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**STRUCTURE AND CLASSIFICATION OF SOME
RECENT AND FOSSIL PENEROPLIDS**

By

W. STORRS COLE

January 15, 1965

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STRUCTURE AND CLASSIFICATION OF SOME RECENT AND FOSSIL PENEROPLIDS*

W. STORRS COLE
Cornell University, Ithaca, N. Y.

ABSTRACT

Recent peneroplids are a profitable group for the study of specific variation. Abundant, well-preserved specimens are available, and there is the possibility that postulates made from the analysis of nonliving tests may eventually be proven correct or incorrect by life history studies which are not possible with fossil specimens. Several Recent species of peneroplids belonging to the genera *Peneroplis*, *Archaias*, *Sorites*, and *Marginopora* are analyzed. *Amphisorus* Ehrenberg, 1839, is demonstrated to be a synonym of *Marginopora*. Although *Sorites marginalis* (Lamarck), a common Indo-Pacific species, has been reported from the Caribbean area, all the Caribbean records which could be checked are erroneous. Fossil specimens from the Miocene assigned to *Archaias floridanus* are the only specimens from the geologic past which are discussed.

INTRODUCTION

In recent years several important articles on the life history of selected species of the so-called "smaller" Foraminifera have been published of which an outstanding example is the detailed study of *Spiroloculina hyalina* Schulze by Arnold (1964). Research on the life histories of "larger" Foraminifera, living in great abundance in the shallow waters of tropical seas, has not been done. A major purpose of this study is to emphasize the difficulties of classifying certain species in the genera *Peneroplis*, *Archaias*, *Sorites*, and *Marginopora* by study of external appearance and the internal structure of the test. Many of the perplexities which were encountered in this and similar studies (Henson, 1950) could be obviated if the life histories of certain Recent critical species were known in detail.

Interpretation by means of the test alone is always open to challenge as the decision of degree of variation to be accepted between specimens in delimiting a species is subjective. Moreover, tests may reflect different developmental stages. Without actual observation of living specimens it may be difficult, or even impossible, to correlate tests at one stage of development with those at another stage. Thus, "form" species and even "form" genera are described either on variants or on developmental stages within a species.

One of the common genera of shallow waters of the Caribbean area is *Archaias*. Specimens from a single locality have been assigned most

*The cost of the printed plates was given by the William F. E. Gurley Foundation for Paleontology of Cornell University. Richard Margerum, departmental laboratory technician, assisted me by preparing a vast number of specimens and his patient hours of labor enabled me to complete this study started several years ago.

commonly to two species, *A. angulatus* and *A. compressus* (Cushman, 1930, pp. 46, 48). Others (Smout and Eames, 1958, pp. 210, 222) recognized two genera, *Archaias* for *A. angulatus* and *Cyclorbiculina* for *A. compressus*. This study suggests on the basis of internal structure that only one species, *Archaias angulatus*, is present. *A. compressus* is considered to be only a variant of *A. angulatus* in which the final chambers form an annular series.

Although the conclusions made in this article are based firmly on detailed examination of a large series of specimens, externally and internally, these postulates may be questioned. However, if specimens of the various species could be cultured, proof could be established concerning the degree of variation which occurs within the species.

A considerable part of the nomenclature of the Foraminifera has been developed by the study of fossil specimens because of the importance of these organisms in stratigraphic correlation. Great emphasis has been given to the description of new species and to the erection of new generic names to accommodate these species. In many instances possible variation between specimens and their potential developmental stages have been neglected or ignored. Thus, "The literature has become clogged with these names . . ." (Cole, 1962, p. 29).

As most of the species discussed in this article are still living, the interpretations given could be checked readily by observation of cultured specimens. If the postulates made by study of the external appearance and internal structure were substantiated by life history studies of these and other living species of "larger" Foraminifera, the interpretations of fossil specimens could be improved.

However, life history studies might demonstrate that variation is not so extreme as studies of the test alone have suggested. If this is so, the endless division of specimens into species and genera, which has been the fashion in recent years, would have to be accepted.

Until life history studies are made, this analysis of certain relationships of the peneroplids is offered as a tentative solution to the classification of these species. Numerous illustrations are given so that data will be available for other interpretations. No claim is made that my interpretations are the only possible solution.

Recently, Smout (1963) reviewed the nomenclature of certain of the genera and species discussed in this article. He concluded (p. 261) that "*Amphisorus hemprichii* is merely a varietal form of '*O.* orbiculus . . .',

whereas my interpretation is that "*A.*" *bemprichii* is a variant of *Marginopora vertebralis*. Smout (1963, p. 261) also proposed that specimens here referred to *Sorites marginalis* (Lamarck) be given a new specific name "*Orbitolites*" *carpenteri*. He stated (p. 262) "The specimens described by Carpenter (1883) as '*O.*' *marginalis* are most unlikely to be conspecific with the specimens given the name by Lamarck; they were from the Pacific Ocean, not the Mediterranean . . ." Although Smout may be correct that *Sorites marginalis* does not occur in the Mediterranean, there is still the possibility that this species does occur there, and that Lamarck had such specimens.

Many of the specimens which are illustrated are discussed, but additional figures have been given so that details which may have been overlooked are available from as many specimens as possible. All of the specimens are deposited temporarily in the Cole collection at Cornell University but will be transferred eventually to the U.S. National Museum.

LOCALITIES

Pacific area

- Loc. 1—Reef flat, windward reef, water depth six inches at low tide, Bikini Island, Bikini Atoll, collected by John W. Wells, 4 August 1947.
- Loc. 2—Channel between Chittakinmatoroen and Autore Islands about 200 yards inward from seaward windward reef with algal ridge, Arno Atoll, collected by John W. Wells, 18 June 1950.
- Loc. 3—Foraminiferal sand from storm breach in main channel to the sea, Kayangle Islands (Ngariungs Island), Palau Islands; collected by Preston E. Cloud, Jr., and Gilbert Corwin, 10 September 1948.
- Loc. 4—Reef off the village of Odomari, Okinawa-Shima, Ryukyu Islands, collected by A. R. Loeblich, Jr., 12 May 1945.
- Loc. 5—Reef off the village of Ogimi, Okinawa-Shima, Ryukyu Islands, collected by A. R. Loeblich, Jr., 12 June 1945.

Philippine area

- Loc. 6—*Albatross* sta. D-5133, island off Panabutan Point, N.52°E., 1.5 miles, at depth of 38 fathoms; specimens loaned by the U.S. National Museum.

African area

- Loc. 7—Reef adjacent to Materno Island, Ibo Bay, Portuguese East Africa, purchased from the late Arthur Earland.
Loc. 8—Shore sand, Mozambique Island, Portuguese East Africa, purchased from the late Arthur Earland.

Caribbean area

- Loc. 9—Shallow water dredging off Barbados Island, British West Indies, purchased from the late Arthur Earland.
Loc. 10—Cercado de Mao, Bluff 3, Santo Domingo, from the Cornell University Collection.

Florida

- Loc. 11—Tenmile Creek, from bridge to 0.5 mile below bridge on the Marianna-Clarksville road, 22 miles south of Marianna, Calhoun County, collected by G. M. Ponton, November 1929.
Loc. 12—Beach sand near Upper Matcumbe Key, Florida, collected by Herman Gunter and J. H. C. Martens.
Loc. 13—Silicified specimens from Hooker's Point, Tampa Bay, from the Florida Geological Survey in 1945.

SYSTEMATIC DESCRIPTIONS

Genus **PENEROPLIS** de Montfort, 1808

Type species, *Nautilus planatus* Fichtel and Moll, 1798.

Peneroplis planatus (Fichtel and Moll) Pl. 2, figs. 1, 2; Pl. 4, fig. 6
1930. *Peneroplis planatus* (Fichtel and Moll), Cushman, U.S. Nat. Mus., Bull. 104, p. 39, pl. 14, figs. 6, 7 (references).

This species, the type species of *Peneroplis*, is “. . . abundant in the Mediterranean and in the Indo-Pacific, but does not, as far as I have seen, come into the West Indian region . . .” (Cushman, 1930, p. 39). Specimens of this species occurred in abundance at localities 3 (Palau Islands) and 5 (Ryukyu Islands). A median section (Pl. 2, fig. 1) and a transverse section (Pl. 2, fig. 2) of specimens from locality 3 are illustrated. Other specimens (Pl. 4, fig. 6) from locality 3 were embedded in balsam and ground so that a part of the exterior wall was retained in places (Pl. 4, fig. 6, top) although elsewhere the exterior wall on the ground side was removed so that the interior of the specimens could be examined.

Externally (Cushman, 1930, pl. 14, figs. 6a, 7a), the wall of the test has pronounced striae which are arranged perpendicular to the sutures. When the wall of the test is examined by transmitted light, the striae are opaque, whereas the intervening areas between the striae are translucent (see: pl. 55, figs. 4, 6, Hofker, 1930). Moreover, if the test is embedded in balsam and completely dissolved with acid, the former position of the striae still show. The chamber wall obviously is composed of two distinct sectors, the translucent thinner parts between the striae and the opaque thickened parts, the striae. As the interior walls of the chambers are smooth, the striae represent external thickening of the chamber wall.

Henson (1950, p. 14) stated "External ornamentation is usually regarded only as a specific character among the foraminifera and is typically constant with the species of the Peneroplidae . . ." However, Hofker (1951, p. 226) regarded ornamentation as a characteristic of generic importance. He restricted *Peneroplis* to species with striae and erected the genus *Puteolina* (Hofker, 1951, p. 450) for peneroplids whose ornamentation consisted of irregularly placed pits. Loeblich and Tappan (1964, p. 482) stated "We do not regard ornamentation as of generic importance," an opinion on which there is general agreement.

The presence of striae in the type species of *Peneroplis* demonstrates that there is selective and unequal deposition of the shell material. Although such accumulations cause the formation of external striae in *Peneroplis planatus*, selective deposition could produce internal ridges or thickened zones normal to the chamber walls. Internal ridges have been described by Henson (1950, p. 46) as ". . . transverse, subepidermal partitions, normal to the primary septa, and projecting a short distance inward from the lateral walls of the test on both sides, leaving the equatorial zone undivided."

Although Henson (1950, p. 14) regarded external ornamentation, such as striae, as a specific character, he (pp. 5, 8) utilized subepidermal partitions as one of the possible recognition features of a genus. In contradistinction to this concept the presence of subepidermal partitions could be considered homologous to the striae, and, therefore, they would be a specific, rather than a generic, characteristic.

Species of *Peneroplis* might develop either striae or subepidermal partitions as supplemental deposits. However, it is probable that a species would develop one or the other. Moreover, certain individuals within a species, because of ecological or physiological conditions, might not

develop either striae or subepidermal partitions. Thus, individuals within a species could range from those whose shell wall was unthickened to other individuals with marked striae, or within another species specimens might range from those without subepidermal partitions to others with marked subepidermal partitions.

Heron-Allen (1915, p. 262) observed that specimens of a single species of Foraminifera growing in a tank to which water "... markedly hard owing to the presence of lime..." was added "... had a tendency to add striae and ridges of secondary shell-substance upon the surface of the shell, and marked carinations and denticulations around its periphery..." Thus, there is experimental evidence to demonstrate that specimens react differently under varying ecological conditions in developing supplemental deposits.

If the argument is accepted that selective thickening of the wall of the test, either externally or internally, is a direct response of the individual to ecological or physiological conditions, the taxonomy of the peneroplids can be simplified. However, the determination of species must be based on the analysis of large numbers of individuals arranged in series and studied both externally and by thin sections.

Peneroplis proteus d'Orbigny

Pl. 1, figs. 1-9, 11-16; Pl. 5, fig. 3

1839. *Peneroplis protea* d'Orbigny, in De la Sagra, Hist. Fis. Pol. Nat. Cuba, "Foraminifères," p. 60, pl. 7, figs. 7-11.
1899. *Peneroplis pertusus* Flint, not Forskal, U.S. Nat. Mus., Rep., p. 304, pl. 48, fig. 4.
1899. *Peneroplis pertusus discoidens* Flint, U.S. Nat. Mus., Rep., p. 304, pl. 49, figs. 1, 2.
1899. *Orbitolites marginalis* Flint, not Lamarck, U.S. Nat. Mus., Rep., pp. 304, 305, pl. 50, fig. 2; pl. 51, fig. 1.
1930. *Peneroplis proteus* d'Orbigny, Cushman, U.S. Nat. Mus., Bull. 104, pp. 37, 38, pl. 13, figs. 1-17.
1930. *Peneroplis discoidens* Flint, Cushman, U.S. Nat. Mus., Bull. 104, p. 41, pl. 15, figs. 6-8.
1930. *Sorites marginalis* Cushman, not Lamarck, U.S. Nat. Mus., Bull. 104, pp. 49, 50, pl. 18, figs. 1-4.
1930. *Praesorites orbitolitoides* Hofker, Monog. 4, Siboga Expedition, Pt. 2, pp. 194-151, pl. 55, figs. 8, 10, 11; pl. 57, figs. 4, 6; pl. 58; pl. 61, figs. 3, 14.
1950. *Peneroplis proteus* d'Orbigny, Henson, West Yorkshire Printing Co. Ltd., Wakefield, England, p. 13, pl. 9, fig. 2.
1950. *Archaias* sp. x Henson, West Yorkshire Printing Co. Ltd., Wakefield, England, p. 41, pl. 9, fig. 3.
1950. *Praesorites orbitolitoides* Hofker, Henson, West Yorkshire Printing Co. Ltd., Wakefield, England, pp. 54, 55.
1951. *Puteolina protea* (d'Orbigny), Hofker, Roy. Micro. Soc., Jour., ser. 3, vol. 71, pp. 452-455, text figs. 38-40 (1952).

1952. *Orbitolites annulatus* Hofker, Roy. Micro. Soc., Jour., ser. 3, vol. 72, pp. 103, 104, text fig. 52.

1952. *Orbitolites orbitolitoides* (Hofker), Hofker, Roy. Micro. Soc., Jour., vol. 72, pp. 105-109, text figs. 53-55.

Flint (1899) beautifully illustrated Caribbean specimens, all of which are considered in this article to represent one species, under the names *Peneroplis pertusus* (pl. 48, fig. 4), *Peneroplis pertusus discoideus* (pl. 49, figs. 1, 2), and *Orbitolites marginalis* (pl. 50, fig. 2; pl. 51, fig. 1). In 1930 Cushman gave an extensive and clear series of illustrations of Caribbean specimens which he assigned to the following species: *Peneroplis proteus* (pl. 13, figs. 1-17), *Peneroplis discoideus* (pl. 15, figs. 6-8), and *Sorites marginalis* (pl. 18, figs. 1-4). All of these specimens were present in the sample from locality 9 (Barbados) in abundance and could be identified readily by means of the illustrations given by Flint and Cushman.

The illustrations of *Peneroplis proteus* (Cushman, 1930, pl. 13, figs. 1-17) show many of the external shapes assumed by specimens in which annular chambers are not developed. Cushman (pl. 15, figs. 6-8) figured three specimens which he assigned to *P. discoideus*. It is apparent, however, that he did not make thin sections of any of these specimens as he (Cushman, 1930, p. 41) stated "The *Peneroplis*, however, does not have its chambers divided into chamberlets, a character easily brought out by moistening the test."

In the series of specimens from locality 9 (Barbados) selected to represent *P. proteus*, the observation was made that a few specimens when moistened had simple, open chambers, whereas the majority apparently had the chambers subdivided into chamberlets. Yet, all of these specimens were identical externally. Therefore, a number of thin sections were made.

The internal structure of the specimens which had simple, open chambers conformed exactly to that of the type species of the genus *P. planatus*. However, the specimens which appeared to have the chambers subdivided into chamberlets proved not to have chamberlets, but subepidermal partitions. Such specimens (Pl. 1, figs. 1-4, 6, 11, 12, 13, 16) internally have a sequence of chambers without subepidermal partitions after which the chambers have the subepidermal partitions.

It should be emphasized that specimens in which subepidermal partitions are developed have an initial part consisting of 12 to as many as 20 chambers following the embryonic chambers in which subepidermal partitions are not developed (Pl. 1, figs. 1-4, 6, 11-13) either in megalospheric

or microspheric specimens. The initial part of these specimens whose terminal chambers contain subepidermal partitions is identical with the tests of other specimens which do not have subepidermal partitions. Subepidermal partitions, therefore, appear to be secondary structures developed in the terminal chambers in response to continued development of the test under favorable ecological conditions.

In median sections (Pl. 1, fig. 11) which are centered the chamber cavities are seen as open, simple, and undivided between the chamber walls. In median sections (Pl. 1, fig. 2) which are not centered perfectly the subepidermal partitions appear in the wall of certain chambers after the initial ones so that these chambers look as if they were subdivided into chamberlets.

Specimens which externally were identified as *P. discoideus* were sectioned (Pl. 1, figs. 3, 4, 6, 11, 13). All of these specimens have subepidermal partitions developed in greater or lesser degree in the terminal chambers. Other specimens (Pl. 1, figs. 1, 12) which were identical with specimens which Cushman (1930, pl. 18, figs. 1-4) illustrated as *Sorites marginalis* also had subepidermal partitions. However, these specimens are microspheric, whereas the specimens identified as *P. discoideus* were megalospheric.

The megalospheric specimens of "*P. discoideus*", of which the specimen (Pl. 1, fig. 3) is similar to one of those illustrated by Cushman (1930, pl. 15, fig. 8), have thick, porcelainous walls. It is impossible to observe the subepidermal partitions by moistening such specimens. However, these subepidermal partitions are present as shown by figure 3, Plate 1.

Transverse sections (Pl. 5, fig. 3) made from specimens with thick, porcelainous walls demonstrate that the wall is thick. Figures 5, 7, 8, Plate 1 represent evolute specimens with a thinner test wall. In each of these three specimens the subepidermal partitions of the final chambers could be observed by moistening the test. However, in external form, arrangement of the apertures and other characters these specimens were identical with specimens which did not have subepidermal partitions.

Specimens from the Caribbean which Hofker (1930, p. 149) originally identified as *Praesorites orbitolitoides* were found to be identical with specimens in the present collection identified as "*P. discoideus*" (compare fig. 4, Pl. 1 with fig. 11, pl. 55, Hofker, 1930) and "*Sorites marginalis*" (compare fig. 12, Pl. 1 with fig. 10, pl. 55, Hofker, 1930). Later, Hofker (1952, p. 105) restudied Caribbean specimens and decided that *Praesorites*

orbitolitoides should be assigned to the genus *Orbitolites*, but he retained *O. orbitolitoides* as a valid species. He (Hofker, 1930, p. 108) also concluded that specimens identified by Cushman as *Amphisorus hemprichii* were *Sorites marginalis*, but he placed this species also in the genus *Orbitolites*.

Henson (1950, p. 47) wrote "The development of subepidermal partitions varies in degree and may be progressive. Thus Mr. T. F. Grimsdale has kindly shown the author certain decalcified preparations from a population of *Peneroplis discoidens* Flint (Honduras) in which there are rudimentary subepidermal partitions faintly but definitely perceptible; this species is, in the author's opinion, closely related to *Peneroplis proteus* d'Orb. The species *Praesorites orbitolitoides* Hofker, also from the Caribbean region, may represent a more advanced stage in the same morphogenetic series."

The observations of Henson clearly substantiate those made in this study. However, Henson was concentrating on Tertiary Peneroplidae from the Middle East, and his study of Caribbean specimens was supplemental to that study. Therefore, he did not commit himself to the exact classification which should be accepted for Recent Caribbean specimens.

The structure of the test of specimens from the Caribbean, identified as *Peneroplis proteus*, is identical with that of the type specimens of the genus *Peneroplis* except that *P. planatus* has a striated surface, whereas *P. proteus* does not. As external ornamentation is not generally accepted as a generic characteristic, *P. proteus* has been assigned to the correct genus.

Specimens of which only half sections (Pl. 1, fig. 3) were made commonly show the row of apertures through the chamber wall. The subepidermal partitions extend across the chamber on either side of an aperture. As the protoplasmic flow should move across the chambers in the direction of the apertures, the margins of these streams of protoplasm would become ideal situations for excess deposits of shell material. Moreover, specimens in which the shell wall is the thickest usually have the best developed subepidermal partitions.

Specimens with subepidermal partitions from the modern seas of the Caribbean area, some of which externally and internally are identical with *P. proteus* except for these partitions, have been assigned to different genera and species, as "*Peneroplis discoidens*", "*Orbitolites orbitolitoides*", "*Sorites marginalis*" and others.

This study demonstrates that all of these specimens with subepidermal partitions should be placed in a single species. However, the question remains whether specimens with subepidermal partitions should be separated either generically or specifically from *Peneroplis proteus*.

If the argument advanced (see: discussion under *Peneroplis planatus*) that these subepidermal partitions are homologous in development to striae, all of these specimens must be assigned to *Peneroplis proteus*. Specimens can be arranged logically in a continuous series in which there is progressive thickening and differential deposition of the test wall, and in which the terminal chambers become annular.

Genus **ARCHAIAS** de Montfort, 1808

Type species, *Nautilus angulatus* Fichtel and Moll, 1798.

1937. *Cyclorbiculina* A. Silvestri—Type species, *Orbiculina compressa* d'Orbigny in De la Sagra, 1839.

Loeblich and Tappan (1964, p. C495) recognized *Cyclorbiculina* as a valid genus following Smout and Eames (1958, p. 222) and stated they "... differentiated *Archaias* with interseptal pillars only from *Cyclorbiculina* with both interseptal pillars and subepidermal partitions." Loeblich and Tappan (1964) illustrated *Cyclorbiculina* by thin sections (figs. 383, 2, 3) after Cole (1957, pl. 24, figs. 4, 9) of specimens from locality 9 (Barbados) identified by Cole as *Archaias compressus* (d'Orbigny), and by external views (fig. 383, 1a, b) after Brady (pl. 14, figs. 9a, b) from the Cape Verde Islands, Atlantic, identified by Brady as *Orbiculina compressa* d'Orbigny.

Henson (1950, p. 43) wrote "The cyclical form *Cyclorbiculina* Silvestri (1937, p. 88) bears the same relation to the spiral *Archaias* as *Archiacina* to *Peneroplis*, and there is no reason to separate it."

Smout and Eames (1958, p. 210) wrote "*O. compressa* commonly occurs with *A. angulatus* and has been extensively confused with it, being one of the species with subepidermal partitions that have given rise to the characters of the genus *Archaias*." On page 222 they stated concerning *Cyclorbiculina compressa* "The early chambers are involute but the flabelliform and cyclical stages are evolute. Other specific differences are given by Hofker (1952a). There is no possibility that the two species intergrade. *C. compressa* has previously been included in *Archaias*, but Henson's revision of the genus excludes it." Yet, Henson (1950, p. 6) placed *Cyclorbiculina* in the synonymy of *Archaias*.

Hofker (1951, p. 460) wrote: "The third form *A. compressus* always turns out to be microspheric . . . It is obvious that Silvestri had specimens similar to the ones which Cushman (1930, pl. 18, figs. 1-4) identified as *Sorites marginalis*." Specimens of this kind are identified in this article as *Peneroplis proteus*.

Typical *Archaias compressus* (d'Orbigny), as illustrated by Cushman (1930, pl. 17, figs. 1, 2) and by Cole (1957, pl. 24), can be separated readily from specimens of *Peneroplis proteus* which superficially resemble "*Sorites marginalis*." Cushman (1930, p. 48) correctly stated that *A. compressus* has a thickened, involute initial part, whereas the initial part of "*Sorites marginalis*" (= *Peneroplis proteus*) is thinner and evolute.

This study will demonstrate that specimens previously identified as *Archaias compressus* not only belong to the genus *Archaias*, but also that they are *A. angulatus*. Therefore, *Cyclorbiculina* A. Silvestri, 1937, is a synonym of *Archaias*.

Archaias angulatus (Fichtel and Moll) Pl. 2, figs. 3-12; Pl. 3, figs. 1-10

1930. *Archaias angulatus* (Fichtel and Moll), Cushman, U.S. Nat. Mus., Bull. 104, pp. 46, 47, pl. 16, figs. 1-3; pl. 17, figs. 3-5 (references and synonyms).

1930. *Archaias compressus* (d'Orbigny), Cushman, U.S. Nat. Mus., Bull. 104, p. 48, pl. 17, figs. 1, 2 (references).

1957. *Archaias compressus* (d'Orbigny), Cole, Bull. Amer. Paleont., vol. 37, No. 163, p. 328, pl. 24, figs. 1-9.

1958. *Archaias angulatus* (Fichtel and Moll), Smout and Eames, Paleont., vol. 1, Pt. 3, pp. 210-213, pl. 39, figs. 1-5.

1958. *Cyclorbiculina compressa* (d'Orbigny), Smout and Eames, Paleont., vol. 1, Pt. 3, p. 222.

Cushman (1930, pl. 17, figs. 3-5) gave clear illustrations of the external appearance of *Archaias angulatus* and of other specimens (pl. 17, figs. 1, 2) which he identified as *A. compressus*. Smout and Eames (1958, pl. 39, figs. 1-5) presented excellent illustrations of the external appearance and internal structure of specimens from Barbados which they identified as *A. angulatus*. Figure 11, Plate 2 is identical with the specimen figured by Smout and Eames (1958, pl. 39, fig. 2) and figure 6, Plate 3 has the same appearance as their figure 3, plate 39.

Although Smout and Eames (1958) did not illustrate specimens of *A. compressus*, they stated that "There is no possibility that the two species intergrade." Smout and Eames (1958, p. 213) considered that *A. angulatus* does not develop annular chambers as they wrote "All records of cyclical chambers in *A. angulatus* also seem to be based on misidentification of *C. compressa*." Although they (Smout and Eames, 1958, p. 222) ob-

served "... in some cases there seems to be a central zone with pillars," they emphasize that "Subepidermal partitions can be seen very clearly ..." in "*Cyclorbiculina compressa*."

All the specimens which were identical externally with illustrations given of *A. compressus* upon sectioning were found to have an initial spire (Pl. 2, fig. 12; pl. 24, fig. 9, Cole, 1957) beyond which the annular chambers develop. But, the plan of the test is such that these annular chambers clearly show that they represent continuing growth of the same structural kind as the initial spire has.

Figures 6, 7, Plate 2 are small specimens composed solely of spiral chambers. Figures 8, 9, Plate 2 demonstrate the manner in which the spiral chambers begin to encircle the initial spire to form the annular, terminal series of chambers observed in figure 12, Plate 2. All the specimens with the annular chambers have an initial, v-shaped (Pl. 2, fig. 12, bottom) bend at the start of the annular series of chambers. This v-shaped bend marks the juncture of the annular chambers with the initial spire, therefore, with continued growth the initial spiral plan of the test becomes annular as the terminal series of chambers are added.

Transverse sections (Pl. 3, figs. 2, 8; pl. 24, fig. 4, Cole, 1957) of "*A. compressus*" are identical with those of specimens identified as *A. angulatus*. Although certain specimens (Pl. 2, figs. 4, 10) have an open space in many chambers along the median plane, these openings are the result of the irregular development of the pillars which have not as yet been added in the median zone but are strongly developed adjacent to the median zone.

Figure 4, Plate 3 represents the central part of figure 11, Plate 2, a typical, nonannular representative of *A. angulatus*, and figure 10, Plate 3 is the central part of figure 12, Plate 2, an excellent example of a specimen of "*A. compressus*." These illustrations (Pl. 3, figs. 4, 10) not only show the small, round pillars excellently but also clearly demonstrate that the structures are the same, except one specimen (Pl. 3, fig. 10) has developed annular chambers beyond the spiral chambers.

Although specimens without annular chambers (*A. angulatus*) can be separated readily from those with annular chambers (*A. compressus*) by external appearance only, their internal morphology is so similar that *A. compressus* is only a variant of *A. angulatus* in which terminal, annular chambers are added.

If the specimens with subepidermal partitions and terminal annular chambers identified by Cushman (1930, pl. 18, figs. 1-4) as *Sorites marginalis* (= *Peneroplis protens*) are eliminated, the other specimens with terminal annular chambers, formerly identified as *Archaias compressus*, are found to have only transverse pillars. As many of these pillars are developed adjacent to the test wall, they may have a resemblance of subepidermal partitions. However, the structure of "*A. compressus*" is identical with that of specimens classified as *A. angulatus* except for the development of the annular series of chambers.

Although the illustrations given by Henson (1950, pl. 9, figs. 5, 7) of Recent Caribbean specimens identified by him as "*Meandropsina* sp. $\times$ [= *Archaias compressus* auct. (pars)]" are not so clear as might be desired, they seemingly represent *Archaias angulatus*. Henson's figure 5, plate 9, should be compared with figure 11, Plate 2, and his figure 7, plate 9, should be compared with figure 12, Plate 2.

The specimens from the Bohio and Caimito formation (Oligocene) of the Panama Canal Zone which Cole (1957, p. 328) identified as *Archaias compressus* (= *A. angulatus*) are identical with the specimens still living in the Caribbean area. Thus, *A. angulatus* has been established in the Caribbean area from Oligocene to Recent time.

Archaias floridanus (Conrad)

Pl. 4, figs. 1,2,4,5,8; Pl. 5, figs. 1,2,4-6

1846. *Nummulites floridanus* Conrad, Amer. Jour. Sci., ser. 2, vol. 2, p. 399, text fig.

1919. *Orbitolites americana* Cushman, U.S. Nat. Mus., Bull. 103, p. 99, pl. 43, figs. 12-14; pl. 44, figs. 1, 2; pl. 45.

1919. *Orbitolites complanata* var. Cushman, not Lamarck, Carnegie Inst. Washington, Publ. 291, p. 71.

1927. *Archaias floridanus* (Conrad), Vaughan, Acad. Nat. Sci. Philadelphia, Proc., vol. 79, pp. 299-303, pl. 23, figs. 3a-c.

1932. *Sorites* (?) sp. (?) Cushman and Ponton, Florida Geol. Sur., Bull. 9, p. 72, pl. 17, figs. 1-8.

1950. *Meandropsina* sp. Henson, West Yorkshire Printing Co. Ltd., Wakefield, England, pp. 41, 47, pl. 9, figs. 1, 6.

Cushman and Ponton (1932, p. 72) gave excellent illustrations of specimens from the Chipola formation (Miocene) of Florida which they identified as *Sorites* (?) sp. Additional thin sections of specimens from this same locality (locality 11) are illustrated (Pl. 4, figs. 2, 8). In the collection of Cornell University there are several specimens from locality 10 (Santo Domingo) identified by Cushman (1919, p. 71) as *Orbitolites complanata* var. These specimens (Pl. 4, figs. 1, 4, 5), externally and internally, are identical with those from the Chipola formation of Florida.

In addition silicified specimens (Pl. 5, figs. 1, 2, 4-6) from the Tampa limestone (Miocene) of Florida collected at Hooker's Point were available. As certain of these specimens were similar externally to those from the Chipola formation and from Santo Domingo, they were sectioned and were found to be identical with the other two lots of specimens. Presumably these specimens from the Tampa limestone are the same as specimens to which Vaughan (1927, p. 303) referred in the following quotation "Associated with *A. floridanus* . . . are great numbers of a species of *Sorites* which is very close to the species so abundant in the Floridian and Caribbean region, and which has been identified by Cushman as *Orbitolites duplex* Carpenter."

Henson (1950, pl. 9, figs. 1, 6) illustrated thin sections made from specimens from the upper Oligocene or lower Miocene of Vera Cruz, Mexico, which he identified as *Meandropsina* sp. The megalospheric specimen (Henson, 1950, pl. 9, fig. 1) is identical with specimens from Florida (Pl. 4, fig. 8) and Santo Domingo (Pl. 4, fig. 4).

Although adequate thin sections of specimens from the Panama Canal Zone identified by Cushman (1919, p. 99) as *Orbitolites americana* have not been published, these Panamanian specimens are so similar to the Floridian and Santo Domingo specimens that they undoubtedly represent the same species.

The large peneroplid embryonic chambers (Pl. 4, fig. 5) are followed by a short sequence of nonannular chambers of which there are two in the Santo Domingo specimen (Pl. 4, figs. 4, 5), six in the specimen (Pl. 4, fig. 8) from the Chipola formation, and four in the Floridian specimen illustrated by Cushman and Ponton (1932, pl. 17, fig. 7). The best specimen from the Tampa limestone resembles the specimen from the Chipola formation (Pl. 5, fig. 6) and has six nonannular chambers. Beyond the sequence of nonannular chambers the chambers are annularly arranged to the periphery of the test.

Although the chambers appear to be divided into chamberlets the radial divisions which appear are small, round pillars which are identical in shape and construction to those found in *Archaias angulatus* (compare fig. 6, Pl. 5 with fig. 4, Pl. 3).

Some transverse sections (Pl. 4, fig. 1) are similar to ones found by sectioning Recent specimens of *Archaias angulatus* (Pl. 2, fig. 10). However, the Recent specimens of *A. angulatus* in transverse section show two

or more coils of chambers above and below the embryonic chambers, whereas the fossil specimens have only one.

The specimens which have been discussed are associated in the collection from the Tampa limestone with coiled specimens which are the same as Vaughan (1927, p. 301) identified as *Archaias floridanus* (Conrad). These specimens have one or two coils of chambers, and annular chambers are not developed. Many of these specimens are microspheric ones, but one is megalospheric. The median section of this megalospheric specimen (Pl. 5, fig. 4) resembles the one of a specimen from the Chipola formation published by Cushman and Ponton (1932, pl. 17, fig. 4) except the chambers form only one coil.

Thus, both in the Tampa limestone and the Chipola formation there are two kinds of specimens, those with a partial coil of chambers followed by annular chambers, and those with one or two coils of chambers, but without annular chambers. As the essential structure of both of these kinds of tests is similar to that of the type species of *Archaias*, they are placed in that genus.

The specimens in which the chambers are arranged spirally are *A. floridanus*. In another part of this article Recent specimens which develop annular chambers, previously identified as *Archaias compressus*, are proven to be one of the possible variants of *A. angulatus*. Therefore, the fossil specimens with annular chambers which have been assigned most frequently to the genus *Sorites* are here assigned to *Archaias floridanus*.

Genus **SORITES** Ehrenberg, 1839

Type species, *Sorites dominicensis* Ehrenberg, 1839=*Nautilus orbiculus* Forskal, 1775.

Cushman (1927, p. 190) designated as the type of *Sorites*, *S. dominicensis* Ehrenberg, 1839 (p. 134). Although Ehrenberg did not illustrate *S. dominicensis*, he gave the locality from which the specimens were obtained as "Ex insula San Domingo frater misit." Thus, the type species was from the Caribbean and probably was obtained from beach sand.

Loeblich and Tappan (1964, p. C496) stated ". . . the type species of *Sorites* has not been recorded from recent deposits of this area, but has undoubtedly been reported as *Sorites marginalis* from the Dominican area, Cuba, and the Atlantic. The types of Ehrenberg were not available for restudy, and were neither figured adequately nor described originally. *Sorites dominicensis* Ehrenberg, 1839 (nominally the type species) is here

regarded as a junior synonym of *S. marginalis* (Lamarck), 1816, and the generic name is retained on the basis of this well-known species."

The specimens from the Caribbean area identified by Cushman (1930, pl. 18, figs. 1-4) as *Sorites marginalis* are assigned by Hofker (1952, p. 108) to *Orbitolites orbitolitoides* and in this article to *Peneroplis proteus*. Loeblich and Tappan (1964, fig. 385, 1a, b) illustrated under the name *S. marginalis* specimens from the Agua Salada group, Miocene, of Venezuela which Renz (1948, p. 166, pl. 6, figs. 8a, b) had identified as *Sorites dominicensis* Ehrenberg. Although Renz did not illustrate thin sections of these specimens, his figures definitely show that the fossil specimens are similar to, if not identical with, Recent specimens from the Caribbean area which Cushman (1930, pl. 18, figs. 5-7) identified as *Amphisorus hemprichii* Ehrenberg (see discussion under *Sorites orbiculus*).

Although *Sorites marginalis* has been listed as occurring in the Caribbean area both as fossil and living, examination of the records indicates that all these identifications are incorrect. However, *Sorites marginalis* is a well-documented species of the Indo-Pacific area. Thus, *Sorites dominicensis* Ehrenberg can not be a junior synonym of *S. marginalis* (Lamarck).

However, *Sorites dominicensis* Ehrenberg from the Recent Caribbean area can be equated reasonably with *Sorites orbiculus* Forskal, 1775. Ehrenberg (1839, p. 134, pl. 3, figs. 2a-d) recorded and illustrated specimens from "In littore libyco et in Mari rubro" which are comparable to Recent specimens from the Indo-Pacific area (Pl. 6, fig. 3) and from the Caribbean area (Pl. 6, fig. 1). From the available data it appears that *Sorites dominicensis* is a junior synonym of *Sorites orbiculus*, thus *S. orbiculus* would be the type of *Sorites*.

***Sorites orbiculus* (Forskal)**

Pl. 6, figs. 1-5, 7,9; Pl. 7, figs. 1-8, 10-12; Pl. 8, figs. 7-9

1775. *Nautilus orbiculus* Forskal, Descriptiones animalium (Post mortem auctoris editit Carsten Niebuhr), Copenhagen: Moller, p. 125.

1839. *Sorites orbiculus* Forskal, Ehrenberg, Abhand. Konig. Akad. Wissench. Berlin (Jahre 1838), p. 134, pl. 3, figs. 2a-d.

1930. *Amphisorus hemprichii* Cushman, not Ehrenberg, 1839, Cushman, U.S. Nat. Mus., Bull. 104, pp. 51, 52, pl. 18, figs. 5-7.

1961. *Sorites orbiculus* Ehrenberg, Lehmann, Eclogae geol. Helvetiae, vol. 54, No. 2, pp. 641-643, pl. 8, figs. 1-8.

Specimens from locality 9 (Barbados) which externally (Pl. 6, fig. 1) were identical with the illustrations given by Cushman (1930, pl. 18, figs. 5-7) of *Amphisorus hemprichii* were sectioned (Pl. 6, fig. 2; Pl. 7, figs.

2, 10). These tests are composed of a single layer of chamberlets (Pl. 7, fig. 2).

Numerous specimens from locality 1 (Bikini Atoll) (Pl. 7, fig. 5), locality 2 (Arno Atoll) (Pl. 6, figs. 4, 5; Pl. 7, figs. 4, 6, 7; Pl. 8, fig. 9), locality 3 (Palau Islands) (Pl. 7, fig. 3; Pl. 8, fig. 8), locality 4 (Ryukyu Islands) (Pl. 7, fig. 8), locality 6 (Philippine Islands) (Pl. 6, fig. 9; Pl. 7, fig. 11) and locality 8 (Mozambique) (Pl. 6, fig. 7; Pl. 7, fig. 1; Pl. 8, fig. 7) were sectioned.

All of these specimens have a peneroplid kind of embryonic chambers beyond which a rude spiral of chambers (Pl. 8, fig. 7) appears. The terminal chambers are annularly arranged. These annular chambers have a characteristic shape with straight radial walls and slightly arcuate outer walls. The radial walls alternate in position.

All of these specimens conform exactly to those excellently illustrated by Lehmann (1961, pl. 8, figs. 1-8).

S. orbiculus is a widely distributed species occurring in the Caribbean and Indo-Pacific areas. This species in the Caribbean area was present as early as the Miocene (Renz, 1948, p. 166).

Sorites marginalis (Lamarck)

Pl. 4, figs. 3,7,9; Pl. 6, figs. 6,8

1816. *Orbulites marginalis* Lamarck, Hist. Nat. Anim. sans Vert., vol. 2, p. 196, No. 1.

1917. *Orbitolites marginalis* (Lamarck), Cushman, U.S. Nat. Mus., Bull. 71, pp. 92-94, pl. 38, figs. 1, 2; text fig. 47.

1961. *Sorites marginalis* (Carpenter), Lehmann, Eclogae geol. Helvetiae, vol. 54, No. 2, pp. 643-645, pl. 8, figs. 9, 10; pl. 11, figs. 1-6.

1961. *Sorites orbitolitoides* Lehmann, not *Praesorites orbitolitoides* Hofker, 1930, Lehmann, Eclogae geol. Helvetiae, vol. 54, No. 2, pp. 645-647, pl. 10, figs. 1-5.

Cole (1954, p. 582, pl. 211, figs. 1, 2) wrote "Specimens identified by Cushman as *Orbitolites marginalis* (Lamarck) from *Albatross* station D 5133 (USNM 15796) were obtained from the U.S. National Museum . . . Cushman (1917, p. 93) gives an accurate illustration and description of the embryonic apparatus and succeeding chambers. These chambers are arranged in a simple planispiral coil between the embryonic and the annular chambers."

At my request N. K. Sachs, Jr., of the U.S. Geological Survey re-examined the sample from *Albatross* station D 5133 and kindly forwarded to me additional specimens. Included in this lot of specimens were several typical specimens of *Sorites marginalis*, some fragments of *Marginopora*

vertebralis and several specimens (Pl. 6, figs. 3, 9; Pl. 7, fig. 11) which were identified as *Sorites orbiculus*.

Other specimens (Pl. 4, figs. 7, 9) of *Sorites marginalis* were found at locality 5 (Ryukyu Islands). The diagnostic structures of this species are so obvious that additional comments are not needed except to indicate that the Caribbean specimens (Pl. 1, fig. 16) which Cushman (1930, pl. 18, figs. 1-4) assigned to "*S. marginalis*" externally have a slightly raised nautiloid-like coil of undivided chambers in the central area, whereas *S. marginalis* (Pl. 1, fig. 10) has an initial coil of subdivided chambers which are not raised.

Genus **MARGINOPORA** Quoy and Gaimard in De Blainville, 1830

Type species, *Marginopora vertebralis* Quoy and Gaimard, 1830

1839. *Amphisorus* Ehrenberg—Type species, *A. hemprichii* Ehrenberg, 1839.

Marginopora vertebralis Quoy and Gaimard

Pl. 7, fig. 9; Pl. 8, figs. 1-6; Pl. 9, figs. 1-12; Pl. 10, figs. 1-8

1830. *Marginopora vertebralis* Quoy and Gaimard in Blainville, Dict. Sci. Nat., vol. 60, p. 377.

1954. *Marginopora vertebralis* Quoy and Gaimard, Cole, U.S. Geol. Sur., Prof. Paper 260-0, pp. 582, 583, pl. 210, figs. 10-13; pl. 211, figs. 3-29.

1961. *Amphisorus hemprichii* Ehrenberg, Lehmann, Eclogae geol. Helvetiae, vol. 54, No. 2, pp. 649-650, pl. 10, figs. 6-9; pl. 11, figs. 1-5.

1961. *Marginopora vertebralis* Quoy and Gaimard, Lehmann, Eclogae geol. Helvetiae, vol. 54, No. 2, pp. 654, 655, pl. 11, figs. 6, 7; pl. 12, figs. 1-7.

In 1954 Cole (p. 582) examined and gave illustrations of Recent and fossil specimens which were identified as *Marginopora vertebralis*. He (p. 583) wrote "At a single station specimens can be found that exhibit throughout their length the 'simple plan.' Others show initially the 'simple plan' which is followed by the 'duplex plan.' Still others have the 'simple and duplex plans' with the 'complex plan' developed in the final annuli. Finally, certain specimens omit the 'simple plan,' and the 'duplex plan' occurs immediately following the embryonic chambers to be succeeded by the 'complex plan' whereas a few specimens show the 'complex plan' starts immediately adjacent to the embryonic chambers.

"To assign these specimens to different genera or even to different species would appear to be a violation of the intimate relationships which appear from the large suite of specimens available. There are no critical structures on which either generic or specific characters can be based.

"Therefore, the generic name *Amphisorus* must become a synonym of *Marginopora*."

Lehmann (1961, p. 649) maintained the genus *Amphisorus* as valid, but he did not refute the contentions of Cole (1954, p. 582) as seemingly he overlooked Cole's article as it is not discussed or listed in the literature cited by Lehmann (p. 665).

Loeblich and Tappan (1964, p. C 496), apparently following Lehmann, regarded *Amphisorus* as a valid genus. As typical illustrations of the genus *Amphisorus*, they figured specimens from Bermuda (fig. 385, 5, 6) after Cushman (1930, pl. 18, figs. 5, 7), identified as *Amphisorus hemprichii*, which are proven here to represent *Sorites orbiculus*. A transverse section (Loeblich and Tappan, 1964, fig. 585, 7) of *A. hemprichii* after Cole (1954, pl. 211, fig. 6) was identified by him as *Marginopora vertebralis* of the "simple type." A part of a median section (Loeblich and Tappan, 1964, fig. 386, 1) after Lehmann (1961, pl. 11, fig. 3) and identified by him as *A. hemprichii* is without question *M. vertebralis*. Finally, the specimen (Loeblich and Tappan, 1964, fig. 386, 2a-c) from Ifaluk Atoll identified by Loeblich and Tappan as *A. hemprichii* is another example of *M. vertebralis*.

Loeblich and Tappan (1964, p. C 498) wrote that *Marginopora* is ". . . without distinct flexostyle such as occurs in *Amphisorus* and *Sorites* . . ." Median sections of *Marginopora* which are exactly centered (Pl. 10, figs. 1,3,4, 6-8) have embryonic chambers which conform exactly to those of *Sorites* as they have an initial chamber through the wall of which a large stolon opens into the so-called flexostyle which in turn opens into the second embryonic chamber (= "vorhof" of Lehmann, 1961).

Median sections (Pl. 10, fig. 2) which are parallel to, but above, the median plane have embryonic chambers which appear to be bilocular of a "eulepidine" kind. Thus, the diagram given by Lehmann (1961, fig. 40) to illustrate the embryonic apparatus of *Amphisorus* is an exactly centered section of *Marginopora*, whereas his diagram (Lehmann, 1961, fig. 42) of *Marginopora* is from a median section slightly above the median plane. Moreover, the illustration given by Lehmann (1961, pl. 11, fig. 7) of *Marginopora vertebralis* has the same arrangement of the embryonic chambers as does another of his specimens (pl. 11, fig. 2) which he identified as *Amphisorus hemprichii*.

If the median sections of specimens assigned to *Marginopora* and *Amphisorus* are identical, *Amphisorus* to be a valid genus must be differentiated from *Marginopora* by transverse sections. Therefore, a number of transverse sections (Pl. 8, figs. 1-6; Pl. 9; Pl. 10, fig. 5) were prepared to

supplement the series illustrated by Cole (1954, pl. 211, figs. 3-17). Certain of these sections were photographed both by transmitted light (Pl. 8, fig. 1; Pl. 9, figs. 2, 4) and by reflected light (Pl. 9, figs. 9, 10, 11).

Large specimens (Pl. 9, fig. 4; Pl. 10, fig. 5) have three distinct zones which for convenience are designated the "simple plan" adjacent to the embryonic chambers followed by the "duplex plan" which in turn is followed by the "complex plan." The "duplex" and "complex" plans result from the development of pillars which develop in the median plane of the test as growth occurs.

Some specimens (Pl. 9, figs. 1, 3, 12) have only the "simple plan," others (Pl. 9, figs. 5, 10) have the "simple" and "duplex plans," and still others (Pl. 9, fig. 4) have all three. In occasional specimens (Cole, 1954, pl. 211, fig. 16) the "simple" and "duplex plans" may be omitted as the "complex plan" occurs immediately beyond the embryonic chambers.

The only modification which occurs in the development of the test as viewed in transverse section is the progressive development of a median zone of pillars. Under the most extreme view an addition of this kind must be considered to be a specific character, not a generic one. If this concept is accepted, *Amphisorus* must be a synonym of *Marginopora* as I have already stated (Cole, 1954, p. 583).

Finally, if one considers the progressive development of pillars in the median zone to represent a specific character, it follows that four species (those with a "simple plan," with a "duplex plan," with a "complex plan," and with all three "plans") of *Marginopora* must be recognized. Moreover, all of these species would be associated in single populations and could be separated one from the other only by transverse sections. It would be indeed a taxonomic absurdity to divide such specimens into several species!

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PLATES

EXPLANATION OF PLATE 1

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1.	Etched median surface, x 20, of a microspheric specimen similar to the one illustrated as figure 16.	
2.	Median section, x 20, of a microspheric specimen with an evolute test and subepidermal partitions.	
3.	Median section, x 20, of a megalospheric specimen of which one surface of the test was removed; note the subepidermal partitions in chambers above the initial coil.	
4.	Median section, x 40, of specimen in which the annular chambers are just developing.	
5,7,8.	Transverse sections, x 40, of specimens in which annular chambers are not developed.	
6,11.	Median sections, x 20, of specimens with flabelliform tests; note subepidermal partitions in some of the outer chambers.	
9,15.	Transverse sections, 9, x 20, by transmitted light, 15, x 40, by reflected light, of a microspheric specimen similar to the one illustrated as figure 16; 15, the right hand part of figure 9.	
12.	Median section, x 20, of a microspheric specimen similar to the one illustrated as figure 16.	
13.	Median section, x 40, by reflected light.	
14.	Part of a transverse section, x 40, of a microspheric specimen.	
16.	External view, x 20, of a microspheric specimen similar to specimens identified by Cushman (1930, pl. 18, figs. 1-4) as <i>Sorites marginalis</i> .	
10.	Sorites marginalis (Lamarck)	21
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	All figures, except figure 10, locality 9 (Barbados, Recent).	
10.	Loc. 6 (Philippines, Recent).	





EXPLANATION OF PLATE 2

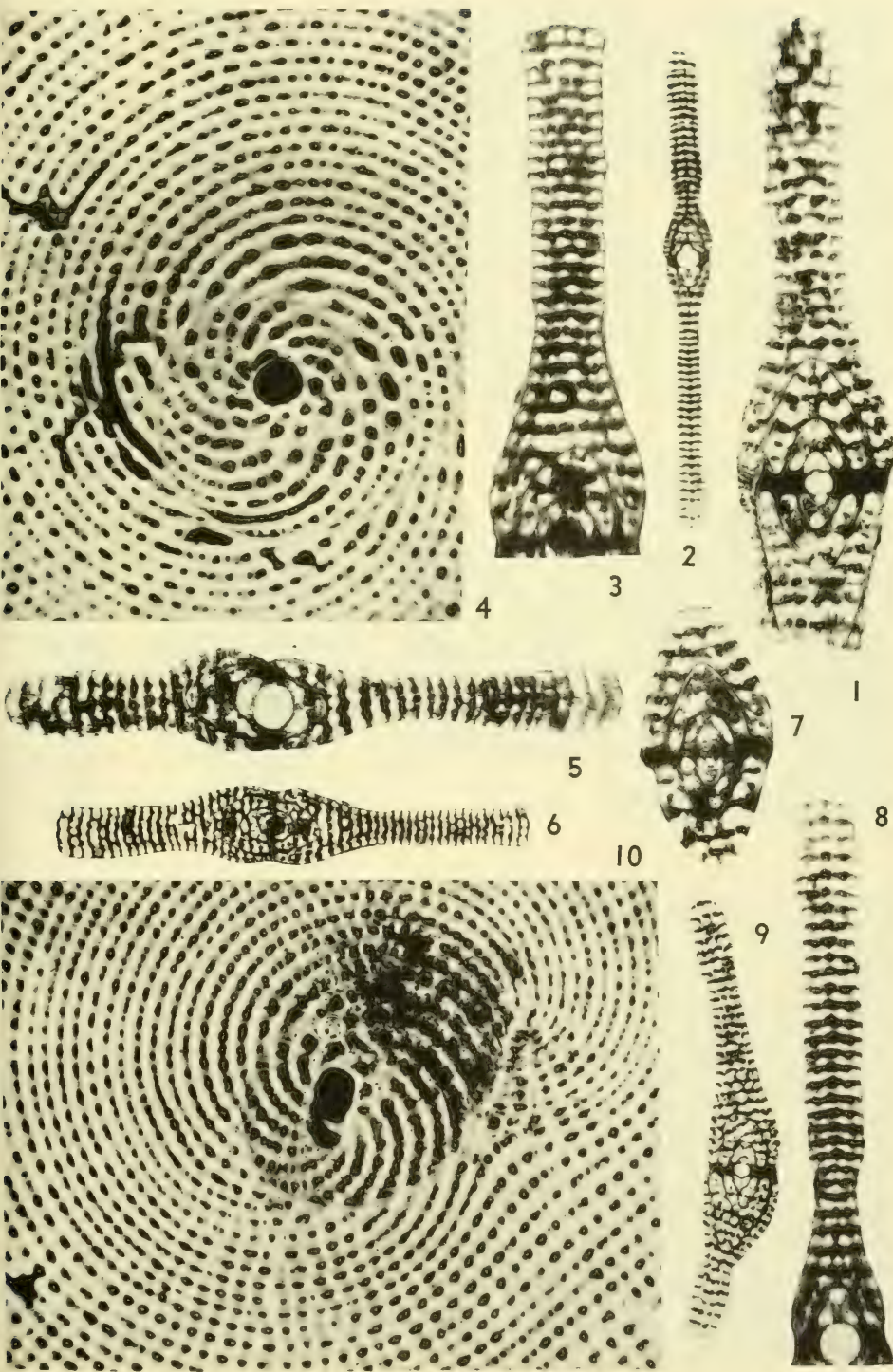
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1, 2. Peneroplis planatus (Fitchel and Moll)	8
1. Median section, x 40.	
2. Transverse section, x 40.	
3-12. Archaias angulatus (Fitchel and Moll)	15
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6-9, 11, 12. Median sections, 6, 7, x 40; 9, 11, 12, x 20; 6-9, 11, specimens without annular chambers; 12, specimen of the " <i>A. compressus</i> " kind with annular chambers (see: fig. 4, Pl. 3, for central part of fig. 11, this Plate, and fig. 10, Pl. 3, for central part of fig. 12, this Plate).	

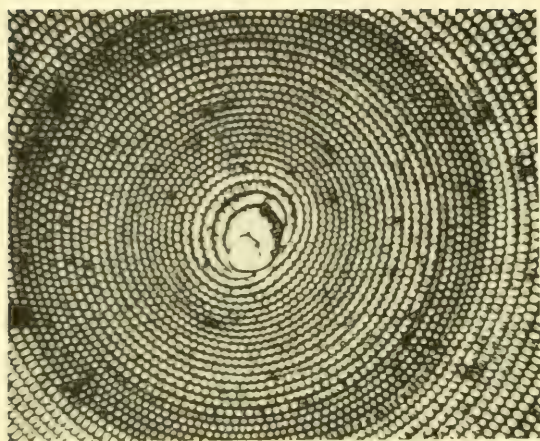
All Recent.

- 1, 2. Loc. 3 (Palau Islands).
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1-10.	Archaias angulatus (Fitchel and Moll)	15
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4,10.	Central parts, x 40, by reflected light; 4, of the specimen illustrated as figure 11, Plate 2; 10, of the specimen illustrated as figure 12, Plate 2.	
	All Recent.	
1,9.	Loc. 12 (Florida).	
2-8,10.	Loc. 9 (Barbados).	





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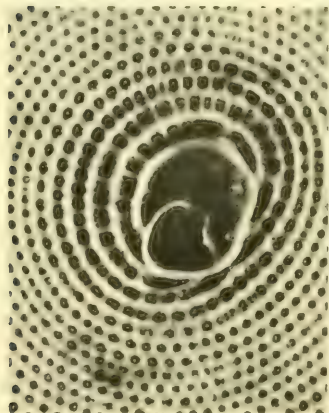
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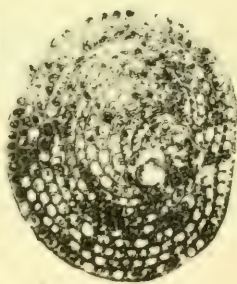
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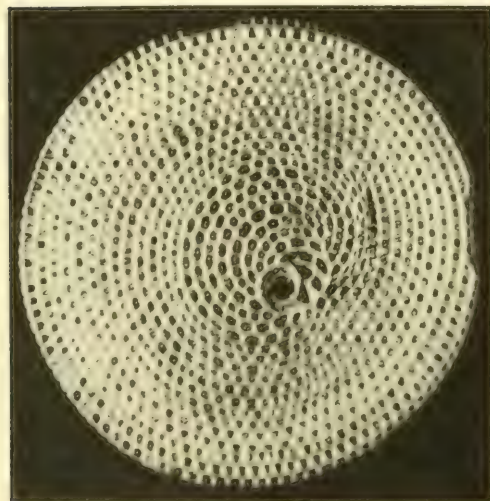
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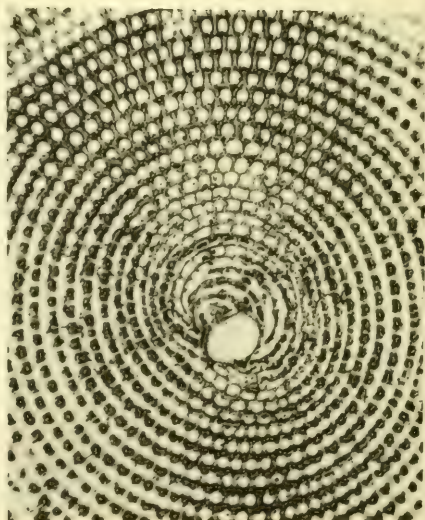
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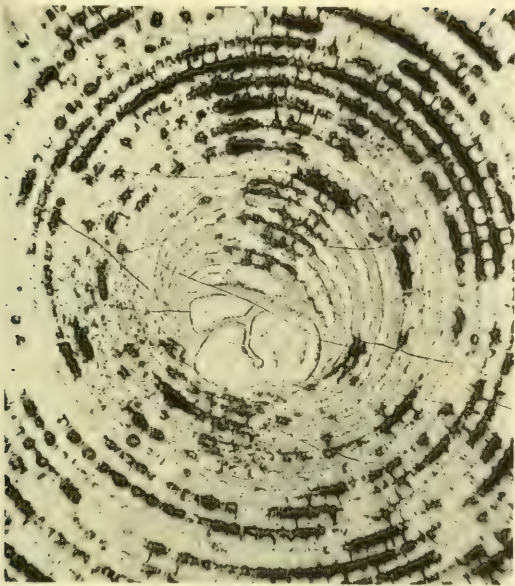
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EXPLANATION OF PLATE 4

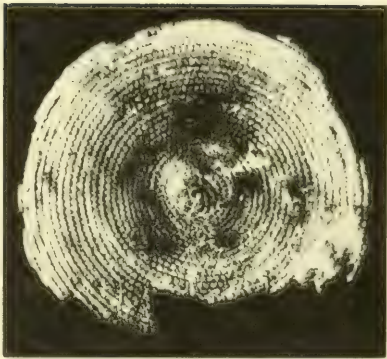
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1, 2, 4, 5, 8. Archaias floridanus (Conrad)	17
1,2. Transverse sections, x 40.	
4,5,8. Parts of median sections, 4, x 20; 5, 8, x 40; 5, the same specimen as figure 4 by reflected light.	
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7. Median section, x 40, of a specimen with few annular chambers.	
9. Median section, x 40, of a specimen with many annular chambers by reflected light.	
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Specimen, x 20, ground nearly to the median plane to illustrate the striae of the test wall.	
1,4,5. Loc. 10 (Santo Domingo, Miocene).	
2,8. Loc. 11 (Florida, Chipola formation, Miocene).	
3,7,9. Loc. 5 (Ryukyu Islands, Recent).	
6. Loc. 3 (Palau Islands, Recent).	

EXPLANATION OF PLATE 5

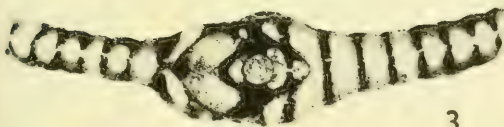
Figure	Page
1, 2, 4-6. Archaias floridanus (Conrad)	17
1. External view, x 12.5, of a specimen whose median section resembles those illustrated as figures 2, 6.	
2, 6. Parts of median sections, x 40, of specimens with 6 chambers forming an incomplete spiral between the embryonic chambers and the outer series of annular chambers.	
4. Median section, x 20, of a specimen whose chambers form a spiral surrounding the embryonic chambers.	
5. External view, x 20, of a specimen whose median section resembles that of the specimen illustrated as figure 4.	
3. Peneroplis proteus d'Orbigny	10
Transverse section, x 40, of a specimen originally identified as <i>Peneroplis discoideus</i> (Flint); compare with figures 5, 7, 8, Plate 1 which represent specimens in which annular chambers are not developed.	
1, 2, 4-6. Loc. 13 (Florida, Tampa limestone, Miocene).	
5. Loc. 9 (Barbados, Recent).	



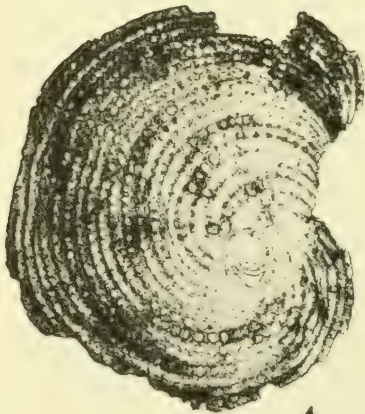
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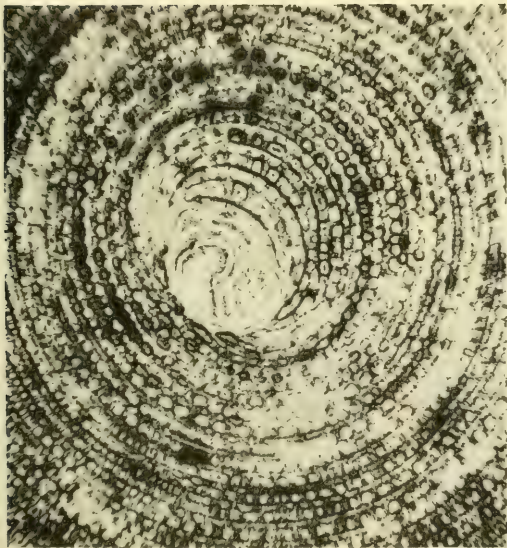
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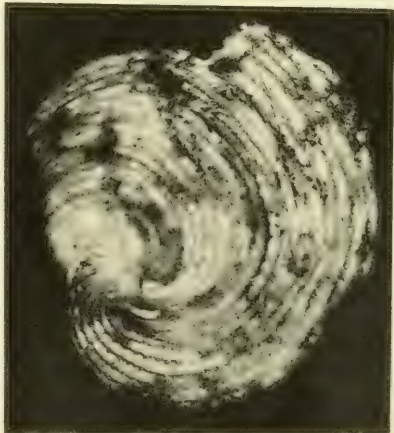
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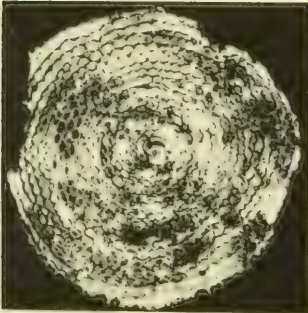
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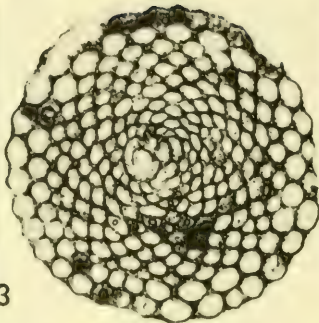
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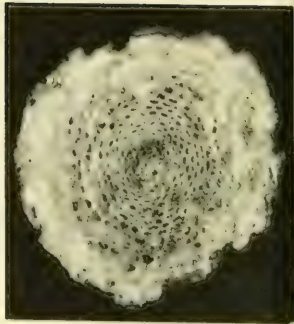
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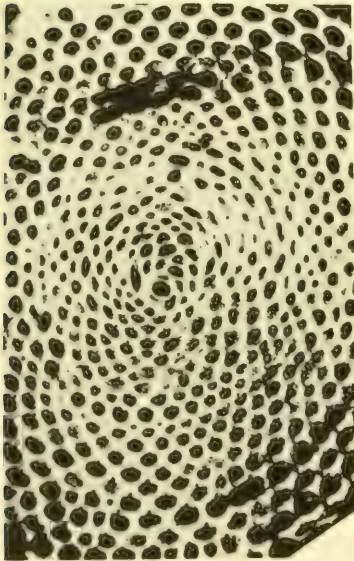
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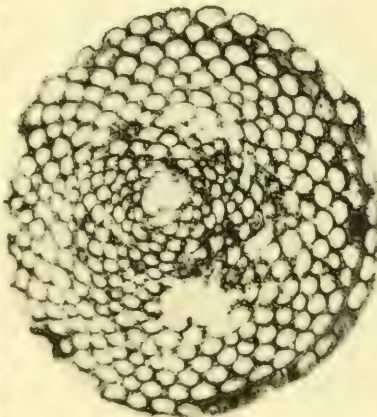
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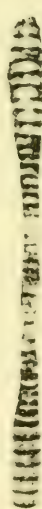
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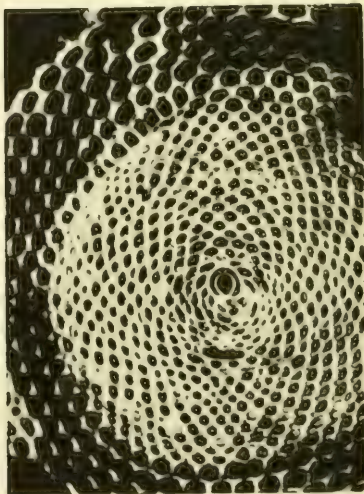
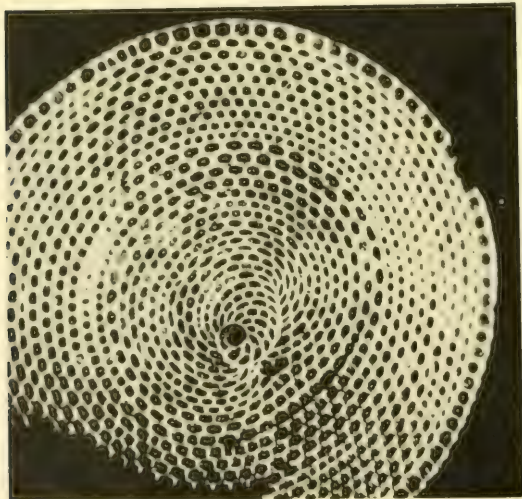
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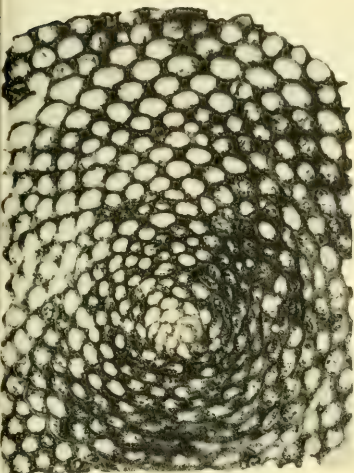


EXPLANATION OF PLATE 6

Figure	Page
1-5, 7, 9. Sorites orbiculus (Forsk.)	20
1,3. External views, x 20.	
2,4,5,9. Median sections, x 40.	
7. Transverse section, x 40.	
6, 8. Sorites marginalis (Lamarck)	21
6. Transverse section, x 40, nearly centered.	
7. Median section, x 40.	
All Recent.	
1,2. Loc. 9 (Barbados).	
3,6,8,9. Loc. 6 (Philippine Islands).	
4,5. Loc. 2 (Arno Atoll).	
7. Loc. 8 (Mozambique Island).	

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Figure	Page
1-8, 10-12. Sorites orbiculus (Forskal)	20
1-6, 11. Transverse sections, x 40.	
7, 10, 11. Median sections, x 40, of megalospheric specimens.	
8. Part of a median section, x 40, of a microspheric specimen.	
9. Marginopora vertebralis Quoy and Gaimard	22
Median section, x 20, of a specimen with a double set of embryonic chambers.	
All Recent.	
1. Loc. 8 (Mozambique Island)	
2, 10. Loc. 9 (Barbados)	
3. Loc. 3 (Palau Islands)	
4, 6, 7. Loc. 2 (Arno Atoll)	
5. Loc. 1 (Bikini Atoll).	
8. Loc. 4 (Ryukyu Islands)	
9. Loc. 7 (Portuguese East Africa)	
11. Loc. 6 (Philippine Islands)	



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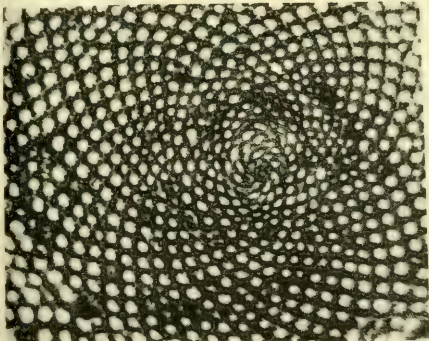
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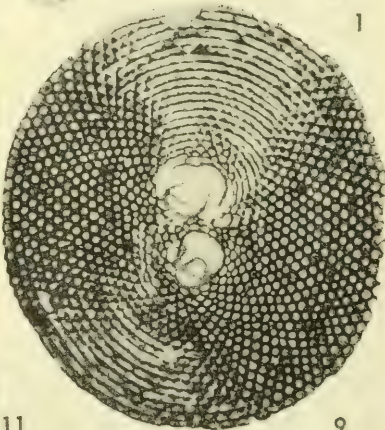
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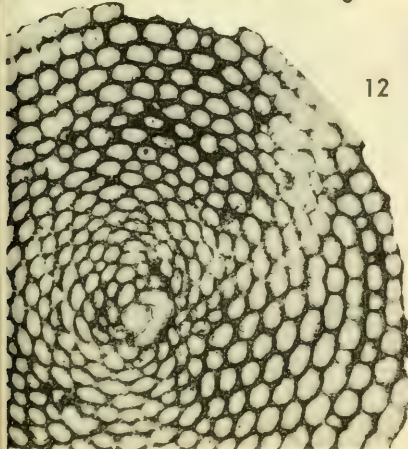
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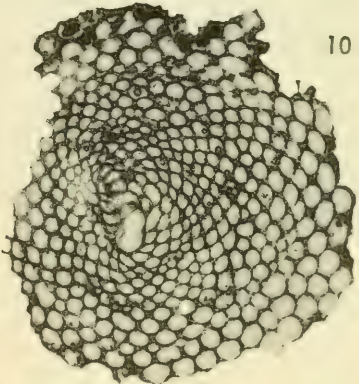
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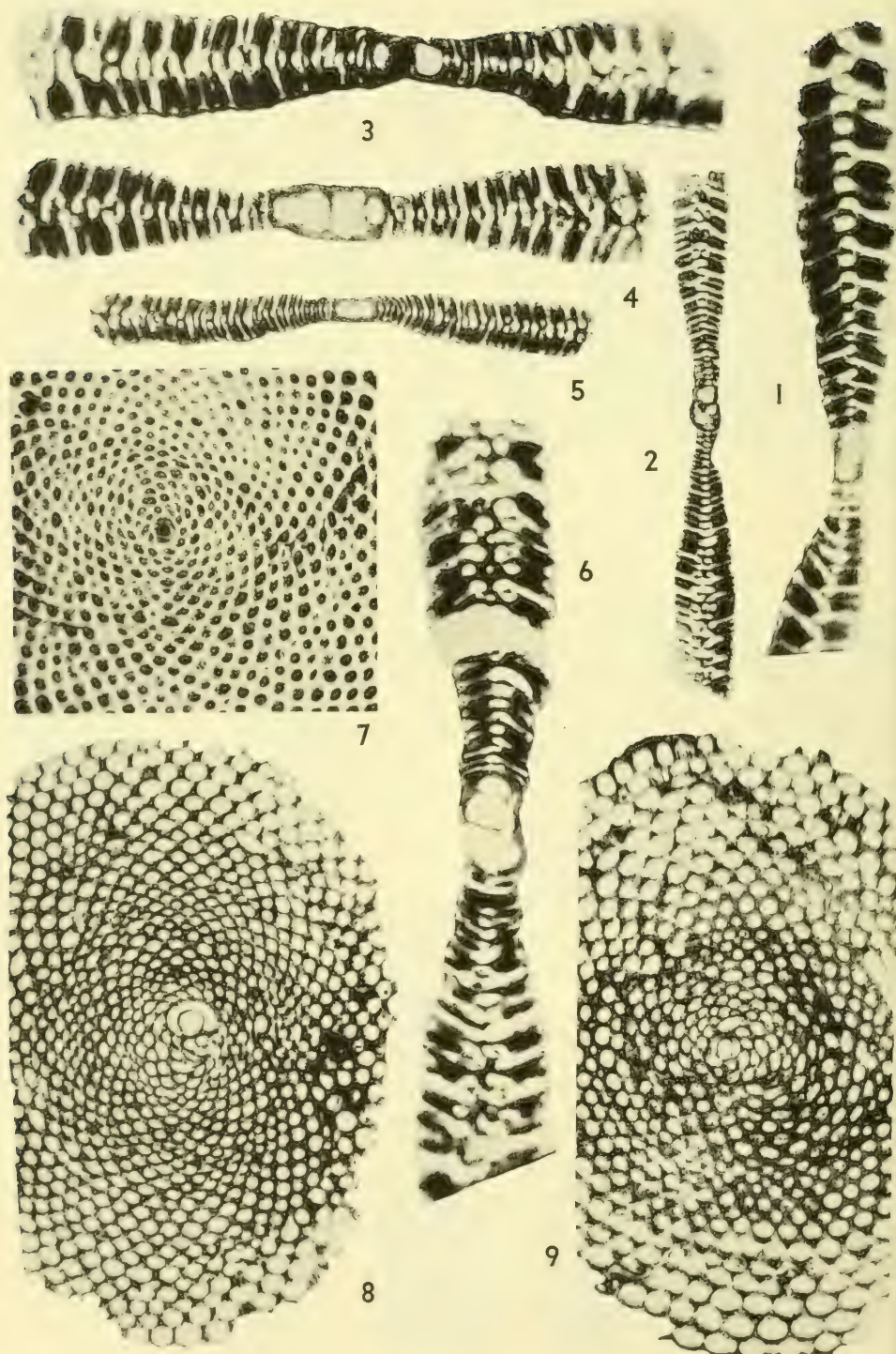
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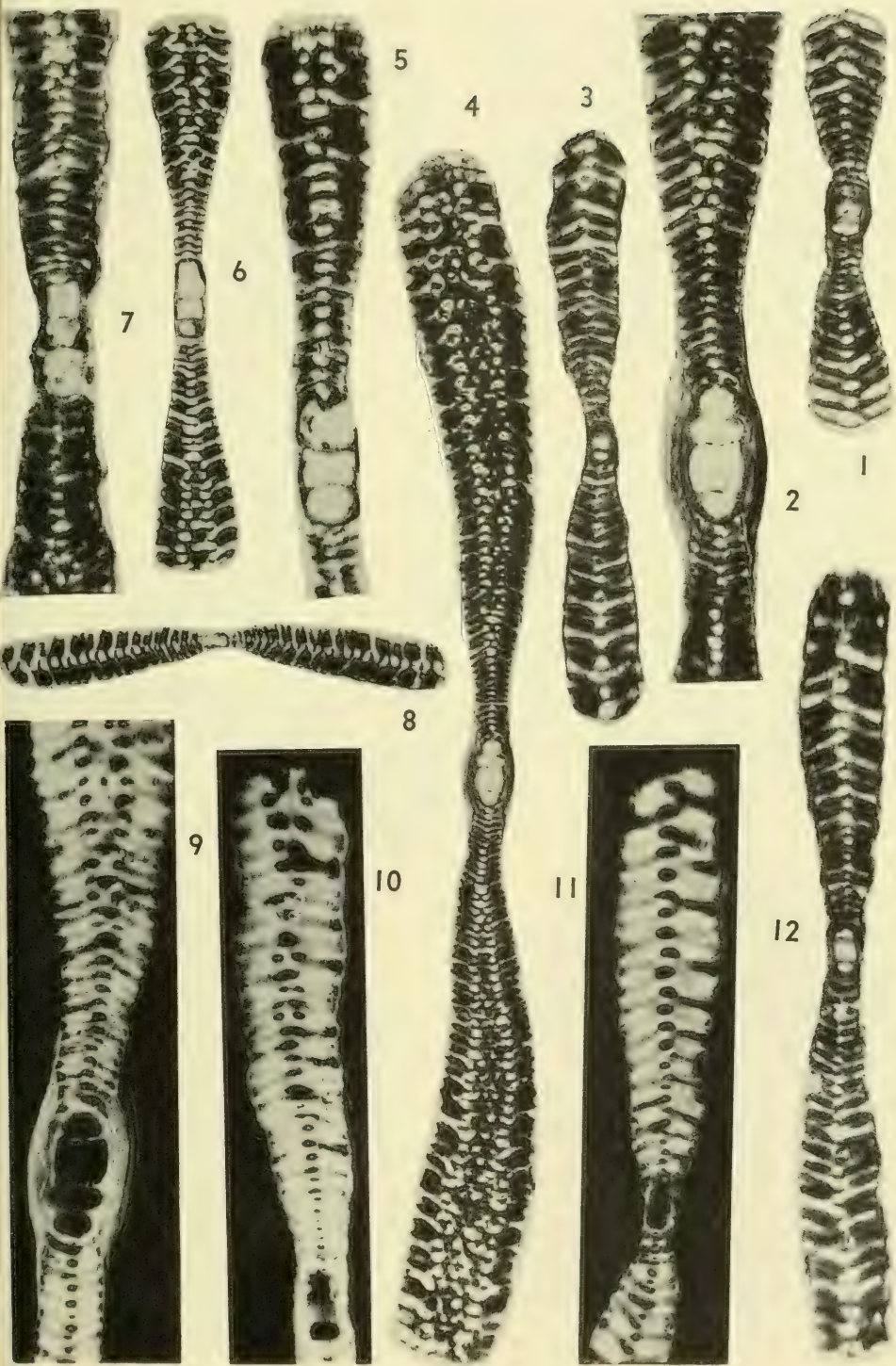


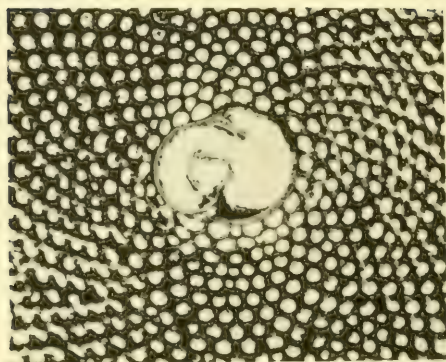
EXPLANATION OF PLATE 8

Figure		Page
1-6.	Marginopora vertebralis Quoy and Gaimard	22
	Transverse sections, 1,3,4,6, x 40; 2,5, x 20; 1, with chambers of the "simple" kind (see same specimen by reflected light, figure 11, Plate 9); 2-5, with terminal chambers of the "duplex" kind; 6, with terminal chambers changing to "complex" kind.	
7-9.	Sorites orbiculus (Forsk.)	20
	Median sections, x 40, to show the embryonic chambers followed by a rude spire of chambers after which the chambers are arranged in annuli.	
	All Recent.	
1,9.	Loc. 2 (Arno Atoll)	
2.4.	Loc. 7 (Portuguese East Africa)	
3,5,6.	Loc. 1 (Bikini Atoll).	
7.	Loc. 8 (Mozambique Island)	
8.	Loc. 3 (Palau Islands)	

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Figure	Page
1-12. Marginopora vertebralis Quoy and Gaimard	22
Transverse sections, 1-7, 9-12, x 40; 8, x 20; 1,3,8, 11,12, with chambers of the "simple" kind; 5-7, 10, with terminal chambers of the "duplex" kind; 2, 4, 9, with terminal chambers of the "complex" type; 2, 9, the same specimen as the one illustrated as figure 4; 11, the same specimen as the one illustrated as figure 1, Plate 8.	
All Recent.	
1,2,4,9.	Local. 4 (Ryukyu Islands)
3.	Loc. 3 (Palau Islands)
5,6.	Loc. 7 (Portuguese East Africa)
7,10.	Loc. 1 (Bikini Atoll)
8,11,12.	Loc. 2 (Arno Atoll)

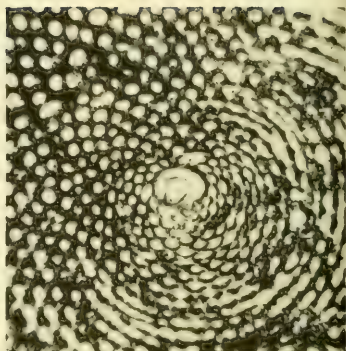




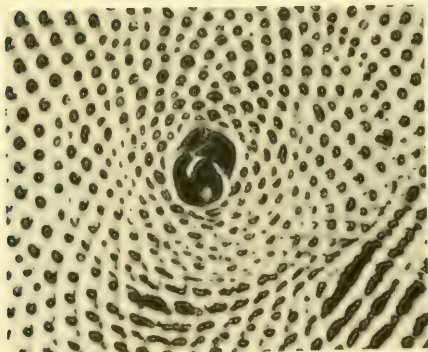
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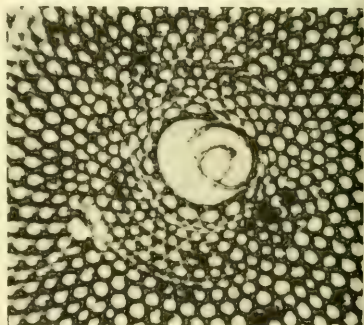
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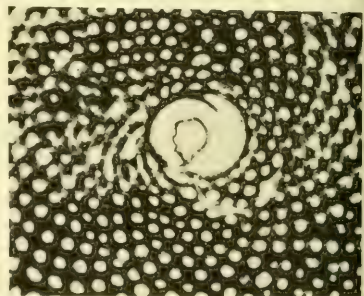
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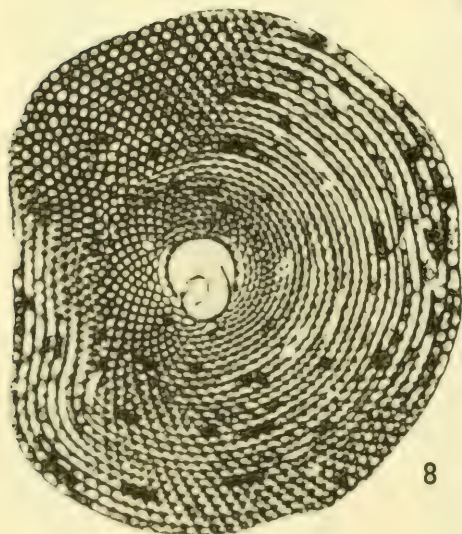
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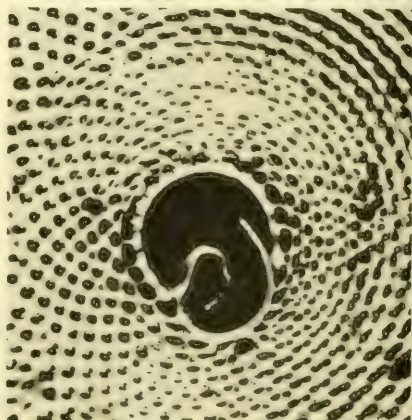
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7

EXPLANATION OF PLATE 10

Figure		Page
1-8.	Marginopora vertebralis Quoy and Gaimard	22
1-4, 6-8.	Median sections, 1-4, 6, 7, x 40; 8, x 20; 1, 3, 4, 6-8, sections exactly centered in median plane; 2, section parallel to, but slightly above, median plane; 4, note inner prolongation to flexostyle; 7, embryonic chambers of the specimen illustrated as figure 8 by reflected light.	
5.	Transverse section, x 40, of a specimen with chambers of the "simple", "duplex" and "complex" kind.	
	All Recent.	
1, 7, 8.	Loc. 7 (Portuguese East Africa)	
2.	Loc. 2 (Arno Atoll)	
3.	Loc. 4 (Ryukyu Islands)	
4-6.	Loc. 1 (Bikini Atoll)	

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**MID-TERTIARY SMALLER FORAMINIFERA FROM A
BORE AT HEYWOOD, VICTORIA, AUSTRALIA**

By

KENNETH J. REED

February 19, 1965

Paleontological Research Institution
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MID-TERTIARY SMALLER FORAMINIFERA
FROM A BORE AT HEYWOOD,
VICTORIA, AUSTRALIA¹

KENNETH J. REED
Cornell University

ABSTRACT

Mid-Tertiary foraminiferal faunas comprising 123 benthonic and 20 planktonic species from 12 cores which range in depth from 191 to 1355 feet in a bore at Heywood, Victoria, Australia, are analyzed. All of the planktonic species and certain of the benthonic species are discussed and figured.

The strata encountered represent a typical marine transgression. The stratigraphically older sediments were deposited in a comparatively shallow-water (20-60 m.) environment, whereas the younger sediments accumulated in a deeper water (up to 95 m.) situation. The benthonic Foraminifera reflect these environmental changes. Abundant planktonic faunas throughout the sequence, however, indicate that connection with the ocean was maintained throughout the depositional cycle.

The sequence is correlated with the Janjukian-Bairnsdalian stages of the Australian Tertiary, and a broad correlation by means of planktonic Foraminifera is made with the *Globigerina ampliapertura-Globorotalia fohsi barisanensis* zones of the Caribbean region. Such correlation is difficult as the Heywood planktonic fauna is dominated by cool-water species, and only a few of the warm-water Caribbean species are present.

The Oligocene-Miocene sequence at Lakes Entrance in eastern Victoria contains a warm-water planktonic foraminiferal fauna in contrast to the cool-water faunas of the western Victorian sequence, found in the Heywood bore. An oceanic circulation at that time, similar to that existing today off the southern Australian coast, is postulated as the cause of the faunal differentiation between the two areas.

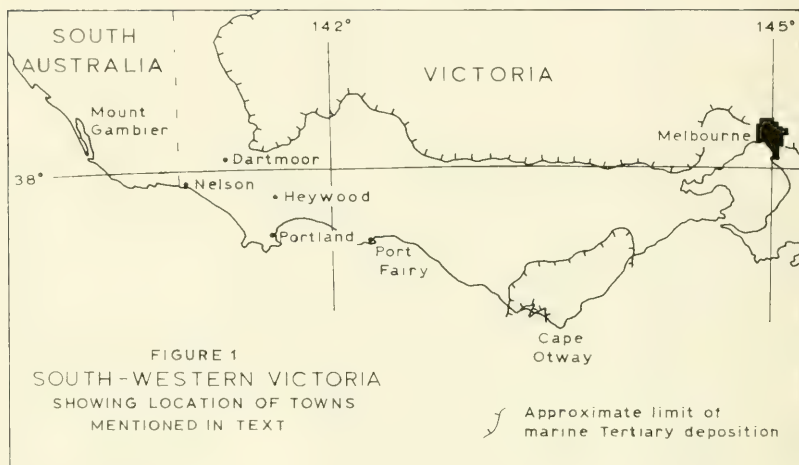
Gaudryina (Gaudryina) heywoodensis Reed is a new name for *Dorothia parri* Cushman, 1936, not *G. parri* Cushman, 1936.

INTRODUCTION

As the foraminiferal faunas from the marine part of the mid-Tertiary sequence of southwestern Victoria have not been described adequately, certain faunas obtained from 12 cores in a well, known as Bore 10, drilled in the Township of Heywood, Normanby County, by the Victorian Department of Mines in early 1961 are analyzed.

Heywood is located approximately 17 miles north of Portland (Fig. 1), and is in the depositional basin known as the Portland Sunklands, a subbasin of the more extensive Otway Basin as defined by the Bureau of Mineral Resources, Geology and Geophysics (Commonwealth of Australia, 1960, p. 32, pl. 1). The Portland Sunklands are separated from the Gambier Sunklands to the west by the Dartmoor Ridge, a geotectonic swelling originating in the basement rocks and active at different times during the Tertiary (Boutakoff, 1952). McQueen (1961) stated that the

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Portland Sunklands extend eastward to Cape Otway (Fig. 1). However, deep-seated structures such as the Mount Eccles Fault (Boutakoff and Sprigg, 1953) or other pre-Tertiary basement faults inferred from geophysical evidence (McQueen, 1961) may restrict the eastward extent of the Portland Sunklands, and thereby form more, as yet unnamed, depositional subbasins within the Victorian part of the Otway Basin.

Tertiary deposition in the Otway Basin began in the Paleocene or Eocene with a thick sequence of largely nonmarine carbonaceous siltstones and quartz sands, ranging in thickness from 450 to more than 5000 feet (McQueen, 1961, p. 11). This was followed in Oligocene and Miocene times by a marine transgression during which from 1180 to over 2800 feet of limestones and marls were deposited.

Although a number of wells have penetrated this thick Tertiary sequence in southwestern Victoria, little has been published on the paleontology of the subsurface rocks. Chapman (1925) listed a fauna of Foraminifera, worms, polyzoans, pelecypods, and gastropods comprising 25 species from cores between 110 and 970 feet in a well drilled at Port Fairy (Fig. 1) and assigned a "Janjukian or Miocene age" to this section. Crespin (1954) published lithologic descriptions and foraminiferal faunal lists of samples from depths between 108 and 7299 feet in a well drilled at Nelson, near the South Australian—Victorian border (Fig. 1). She recognized Janjukian fossils in the upper part of the section, but the section below 976 feet was assigned to the lower and middle Eocene.

Baker and Cookson (1955) revised Crespin's conclusion and correlated the sediments below approximately 4500 feet with the Upper Cretaceous on the basis of the contained microflora. Douglas (1960/1961) made some broad correlations of Lower Tertiary and Mesozoic subsurface rocks from a number of wells in the Western District of Victoria, using dinoflagellates (Deflandreidae), but his samples did not include any from the upper carbonate part of the sequence.

Grateful acknowledgment for their assistance is given to: Dr. W. Storrs Cole of Cornell University, for guidance throughout the entire project; Dr. Richard Cifelli of the U. S. National Museum, Washington, D. C., for suggestions and permission to study the Cushman and U.S.N.M. foraminiferal collections; Dr. D. E. Thomas, Director of the Geological Survey of Victoria, for permission to study the core samples; Mr. R. C. Glenie of the Geological Survey of Victoria, for discussions and for providing stratigraphic information; Mrs. I. Knight of the Geological Survey of Victoria for her drawings of *Cibicides victoriensis*; and Mr. D. C. Brew of Cornell University for reading the manuscript.

STRATIGRAPHY

A lithologic and stratigraphic summary of the Heywood No. 10 Bore, compiled from information in the files of the Victorian Department of Mines (unpublished reports of R. C. Glenie and the writer), is given in Table 1. The twofold subdivision of the Gambier limestone was proposed by Glenie and Reed (1960/1961, p. 42) from the subsurface section observed in Bore No. 3 drilled at Portland by the Victorian Department of Mines. The other stratigraphic units shown were defined by Boutakoff and Sprigg (1953) with the exception of the Belfast mudstone. This unit was named by geologists of the Frome-Broken Hill Company Pty. Ltd. and was applied to Cretaceous marine sediments first found in Mines Department Belfast No. 4 Bore at Port Fairy (McQueen, 1961, p. 11). Ludbrook (1957) used a somewhat different stratigraphic nomenclature for the South Australian part of the Otway Basin, but so far her units have not been distinguished in Victoria.

The sequence penetrated in Heywood No. 10 Bore is similar to that encountered in the Portland No. 3 Bore (Glenie and Reed, 1960/1961). The most significant difference is that the Heywood No. 10 Bore finished in Cretaceous marine sediments assigned to the Belfast mudstone, whereas this formation was not recognized in the Portland Bore. The Tertiary se-

Table 1.- Stratigraphic and lithologic summary of Heywood No. 10 Bore

	Group	Formation	Member	Lithology	Depth (feet)	Thickness (feet)
				Soil and superficial clay	0 - 12	12
Miocene	Glennelg	Gambier limestone	Portland limestone	Pure limestone and marly limestone	12 - 519	507
Oligo- cene			Heywood marl	Marl and marlstone, with pure and marly limestone near base	519 - 1288	769
- - ? - -		Nelson		Sandy limestone and sandy dolomitic limestone, in part glauconitic; dolo- mitic and ferruginous siltstones	1288 - 1373	85
	Knight	Dartmoor		Quartz sand, silty quartz sand, carbonaceous silt- stone, basalt (1423 - 1454), minor coal, dolo- mitic siltstone and sandstone.	1373 - 4238	2865
Eocene		Bahgallah?		Carbonaceous siltstone, in part sideritic, dolomitic sandstone and siltstone, quartz sand, minor coal and dolomite	4238 - 5282	1044
- - ? - -		Belfast mudstone		Carbonaceous siltstone and claystone	5282 - 5390	108
Cret- aceous						

quences of the two bores are comparable except for some differences in thicknesses and the absence of the Whaler's Bluff formation in the Heywood No. 10 Bore.

The youngest stratigraphic unit is the Gambier limestone from which the foraminiferal faunas of eight cores (Table 2) were studied. This formation is highly fossiliferous and grades from a pure limestone (97 per cent soluble carbonate) in its upper part to a marl (40 per cent soluble carbonate) toward the base. It conformably overlies the Nelson formation.

The faunas of two cores (Table 2) from the Nelson formation were examined. The variable lithology of this unit (Table 2) reflects a transitional depositional sequence between the nonmarine Dartmoor formation below and the entirely marine Gambier limestone above. Although an unconformity may be present between the Dartmoor and Nelson formations, there is not sufficient evidence for a positive statement.

The faunas from the Nelson formation, unlike the well-developed ones found in the Gambier limestone, are poorly preserved and have few species. Moreover, it was difficult to separate the specimens in the Nelson formation from the matrix.

Six cores were examined from the nonmarine Dartmoor formation. As these cores were unfossiliferous, this formation is not discussed.

CORRELATION

Correlations have been made with the local stages and faunal units defined by Carter (1958a, b; 1958/59; 1964), and with the planktonic foraminiferal zones of the Caribbean region (see Fig. 2). This latter zonation was established by Bolli (1957), based on earlier work by Cushman and Stainforth (1945), and Stainforth (1948), for the Cipero formation of Trinidad. The validity of this zonation has been shown by its recognition elsewhere (*e.g.*, Mediterranean region—Blow, 1957; Venezuela—Blow, 1959; Saipan—Todd, 1957; Japan—Saito, 1960; Asano, 1962; Philippines—Bandy, 1963). Stainforth (1960) summarized the occurrences of pelagic Foraminifera on both sides of the Atlantic and from this data proposed a correlation between the Caribbean planktonic zones and the European stages. An attempt has been made to correlate the sequence encountered in the Heywood No. 10 Bore with the European stages via the intermediate step of the Caribbean, using Stainforth's conclusions.

Because continuous core samples were not available throughout the entire section, it was impossible to fix accurately the boundaries between

Table 2.- Details of core samples from Heywood Bore No. 10

Core	Depth (feet)	Formation or Member	Lithology	Fauna	
AA	191 - 211	Gambier limestone	Portland limestone	Abundant bryozoa, ostracoda and foraminifera; Occasional brachiopods, gastropods and pelecypods	
AB	403 - 423				
AC	603 - 623		Heywood marl	Pale grey limey marlstone	Abundant bryozoa, ostracoda, foraminifera, echinoid spines and test fragments, <u>Ditrupa</u> (polychaete) tubes
AD	734 - 754				
AE	855 - 875		Grey marlstone		Occasional gastropods and pelecypods
AF	976 - 986				
AG	1095 - 1105				
AH	1211 - 1228				
AI	1315 - 1335	Nelson formation	1. Sandy dolomitic limestone	Occasional bryozoa; rare foraminifera and echinoid fragments. Limonite, glauconite and clay molds of above. Echinoid? fecal pellets.	
			2. Brown micaceous siltstone	Pyritized worm? trails; rare foraminifera. Internal molds	
AJ	1335 - 1355		1. Calcare- ous sand- stone	Fossils rare. Limonite molds and staining	
			2. Grey-brown siltstone	Rare foraminifera and a small pelecypod; in part pyritized	
AK	1468 - 1489		Black micaceous carbonaceous siltstone		
AM	1712 - 1722		Brownish- black micaceous siltstone		
AN	1835 - 1855	Dartmoor formation	Brownish- grey micaceous siltstone	Unfossiliferous. Pyrite absent; occasional carbonized plant material	
AO	1955 - 1975		Dark-brown micaceous carbonaceous siltstone		
AQ	2095 - 2116		Grey micaceous siltstone		
AT	2370 - 2390		Dark-brown micaceous siltstone		

foraminiferal zones, which are indicated on the correlation chart (Fig. 2) as lying somewhere between adjacent cores.

CORRELATION WITH SUBDIVISIONS OF THE VICTORIAN TERTIARY

A subdivision of the Victorian Tertiary from Eocene to Miocene into a sequence of 11 faunal units, each with a diagnostic foraminiferal association of planktonic and benthonic forms was proposed by Carter (1958a). This subdivision gave a paleontological basis for delimiting and correlating most of the well-established Victorian Tertiary Stage Classification originated by Hall and Pritchard (1902) and expanded by later workers (see: Singleton, 1951, for the historical development of this classification). Carter elaborated his subdivision in two subsequent papers (1958b; 1958/59), and later condensed the 11 faunal units into a sequence of 10 foraminiferal zones (1964). As these zones are based on the faunal units, and because some of the Heywood samples have yielded the diagnostic fossils of a particular zone without the zone fossil being present, the subdivision into faunal units rather than into formal zones is followed here.

The foraminiferal associations characterizing the faunal units and their correlation with the local stage names, as given by Carter (1964, table 4), with youngest at top, are summarized below. The last appearance of a particular species is indicated by "(1)" after the name, the first appearance by "(f)".

<u>Stage</u>	<u>Faunal Unit</u>	<u>Foraminifera</u>
Bairnsdalian	11	<i>Orbulina universa</i> (f), <i>O. bilobata</i> , <i>Cibicides victoriensis</i>
Balcombian	10	<i>Globigerinoides transitorius</i> (f), <i>G. glomerosus</i> , <i>Orbulina suturalis</i>
Batesfordian	9	<i>Globigerinoides trilobus</i> with large apertures (f), <i>Lepidocyclus howchini</i> , <i>Cycloclypens victoriensis</i> , <i>Austrotrillina howchini</i>
	8	<i>Globigerinoides ruber</i> (f), <i>Astrononion centroplax</i>
	7	<i>Globigerinoides trilobus</i> (f), <i>G. bisphericus</i> (f), <i>Sherbornina cuneimarginata</i> , <i>Planorbulinella plana</i> (f), <i>P. inaequilateralis</i>
Longfordian	6	<i>Globoquadrina debiscens</i> (f), <i>Globigerina ciperoensis</i> (f), <i>Gypsina howchini</i> (f), <i>Operculina victoriensis</i> (f), <i>Sherbornina cuneimarginata</i> (f), <i>Hofkerina semior-nata</i> (f)

Janjukian	5	<i>Astrononion centroplax</i> (f), <i>Amphistegina lessonii</i> (f), <i>Victoriella conoidea</i> (1)
	4	<i>Globigerina ouachitaensis</i> — <i>G. bulloides</i> group (f), <i>Sherbornina atkinsoni</i> (f), <i>Gümbelina rugosa</i> (1)
Aldingan	3	<i>Victoriella conoidea</i> (f), <i>Globigerina linaperta</i> (1), <i>Vaginulinopsis acanthonucleus</i>
	2	<i>Globigerinoides index</i> (1), <i>Globigerinella micra</i>
	1	<i>Globigerinoides index</i> , <i>Hantkenina alabamensis</i> (1)

In the Heywood samples, faunal units 5, 6, 7, 8, and 11 are definitely recognized. Faunal unit 11 however, is the only one which has the complete association defined by Carter (1964, table 4). Faunal units 4, 9, and 10 are assumed to be present on less reliable evidence.

Globigerina ciproensis, whose initial appearance marks faunal unit 6, is found in core AG with *Astrononion centroplax*. The latter species, however, is not found in core AH, and so faunal unit 5, characterized by the first appearance of *Astrononion centroplax*, must occur between cores AG and AH.

The base of faunal unit 7 is placed between cores AD and AE as *Globigerinoides trilobus* and *G. bisphericus* are first found in core AD. *G. ruber* is found in core AB but probably makes its first appearance earlier. Faunal unit 8, therefore, is placed between cores AB and AC. The association of *Orbulina bilobata* and *O. universa* in core AA indicates faunal unit 11. The extent of this faunal unit above core AA is not known. Faunal units 9 and 10 are placed on the chart (Fig. 2), without any of the diagnostic fossils being recognized, between cores AA and AC, below faunal unit 11 and above faunal unit 8.

Only three of the benthonic Foraminifera used to define the faunal units have been found in Heywood No. 10 Bore. The range of *Astrononion centroplax* in the bore, from cores AD to AG, is somewhat shorter than that recorded by Carter (1964), who found this species in faunal unit 8, which occurs above core AC in the Heywood Bore. *Operculina victoriensis* (= *Camerina complanata*) is found only in the Portland limestone. Carter (1964) recorded its first appearance earlier in faunal unit 6. The increased clay content of the sediments in the Heywood marl indicate turbid waters and a muddy substrate during deposition, possibly an unfavourable environment for this form, which would explain its absence below core

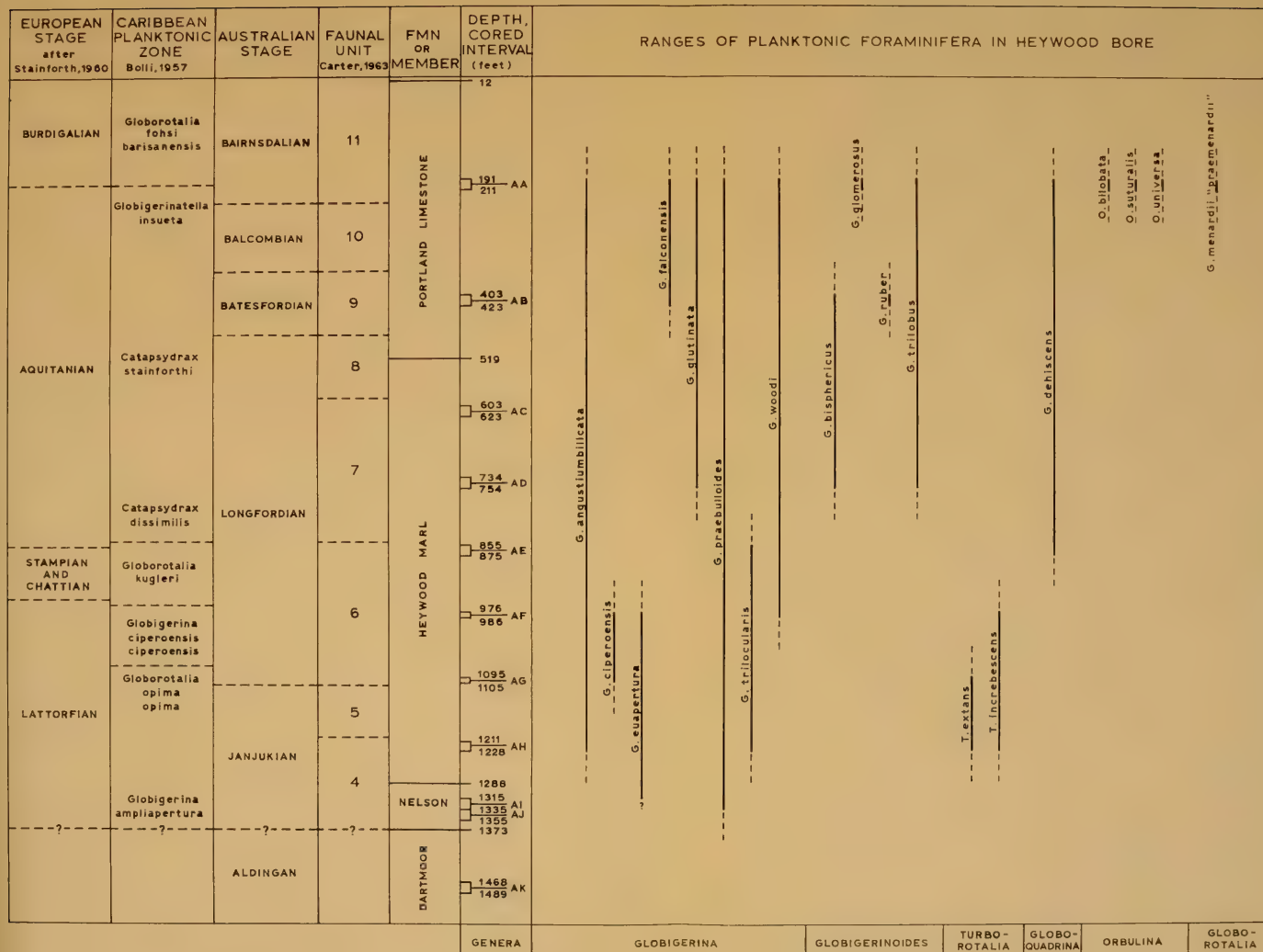


FIGURE 2.- Correlations and stratigraphic ranges of selected species of planktonic Foraminifera

AB. The occurrence only in core AA of *Cibicides victoriensis* agrees with its first appearance in faunal unit 11 as defined by Carter (1964).

The absence of *Victoriella conoidea* (Rutten) [= *V. plecte* (Chapman)]—see: Glaessner and Wade, 1959] in the Heywood Bore is unexpected, because Crespín (1954) has reported this typically Janjukian form from a number of bores in the surrounding area at Dartmoor, Mt. Gambier, Nelson, and Portland.

CORRELATION WITH CARIBBEAN PLANKTONIC ZONES

By means of planktonic Foraminifera, Bolli (1957) established 13 zones within the Oligocene and Miocene of Trinidad, W.I. This zonation has been recognized elsewhere, and is accepted, at least in its broad aspects, as valid over much of the world. The sequence of the eight lower zones, beginning with the youngest, is as follows:

Globorotalia fohsi barisanensis Zone

Globigerinatella insueta Zone [subdivided by Blow (1959) into an upper

Globigerinatella insueta/*Globigerinoides bisphericus* Subzone and a lower

Globigerinatella insueta/*Globigerinoides trilobus* Subzone]

Catapsydrax stainforthi Zone

Catapsydrax dissimilis Zone

Globorotalia kugleri Zone

Globigerina ciperoensis ciperoensis Zone

Globorotalia opima opima Zone

Globigerina ampliapertura Zone

In the Heywood Bore, core AA is correlated with the upper part of the *Globigerinatella insueta* Zone of Bolli (1957) [= *Globigerinatella insueta*/*Globigerinoides bisphericus* Subzone of Blow (1959)], or with the base of the *Globorotalia fohsi barisanensis* Zone, as indicated by the association of *Orbulina universa* and *Globorotalia menardii* "*praemenardii*" with the three variations ("subspecies") of *Globigerinoides glomeratus*. With less certainty, the Gambier limestone below core AA and the Nelson formation have been correlated with the six lower zones of the Caribbean sequence (Fig. 2). Although the characteristic fossils were not found, the *Globigerina ampliapertura* Zone is thought to extend from the Nelson formation into the base of the Heywood marl on the opinion of Jenkins (1960, p. 369), who correlated the basal part of the sequence in the Lakes Entrance Oil Shaft, which contains a similar fauna to that of the lower part of the Heywood sequence, with this Zone.

Jenkins (1960, p. 369) pointed out that some differences in the Tertiary planktonic assemblages of Lakes Entrance in eastern Victoria and those of the Caribbean region do exist, "... due probably to a latitude and depth difference ..." between the two areas. The same is true of the Heywood assemblages and those of the Caribbean. The absence or scarcity of some of the Caribbean zone fossils, particularly in the lower depths of the bore, however, indicates that alternative zonal indices which have a wider distribution should be selected for the geographically different, southern Australian region. "*Globorotalia*" *extans* of Jenkins (1960) may be important in this regard. Its stratigraphic range in the bore corresponds roughly with that given by Jenkins (1960), but insufficient knowledge at present concerning its exact stratigraphic and geographic distribution would make the establishment of a zone based on this form somewhat tenuous.

Jenkins (1960, p. 370) discussed the stratigraphic range of *Globoquadrina debiscens* in Australia and New Zealand as compared with that in the Caribbean region. In the Heywood Bore, this species was found abundantly in cores AA and AB but only rarely in core AE and not at all in cores AC and AD. The stratigraphic occurrence of *G. debiscens* in the bore is thus earlier than in the Caribbean but later than recorded by Jenkins (1960) in the Lakes Entrance Oil Shaft. Ecologic factors are thought to be responsible for its scarcity below core AB in the Heywood bore (see: section on "Influence of oceanic circulation on planktonic fauna").

The range of *Globigerinoides bisphericus* in Heywood No. 10 Bore is more comparable to that recorded by Carter (1958a, b; 1958/59; 1964) than to the short time range ascribed to this form by Bolli (1957), Blow (1959), and Jenkins (1960). Jenkins (1960, p. 353) questioned this discrepancy, suggesting that Carter's earlier identifications of this species were erroneous. The present work, however, supports Carter's original extended range. It may be that *G. bisphericus* originated in the southern Australian region and later spread to other areas in a similar manner to that described for *Globoquadrina debiscens* by Jenkins (1960, p. 370). Further work is needed to establish this postulate.

CORRELATION WITH EUROPEAN STAGES

Although the Caribbean planktonic zones have been recognized in Europe, their exact correlation within the European stages is still in doubt. The existing confusion is well exemplified in papers by Drooger (1956), Hornibrook (1958), Glaessner (1959), Stainforth (1960), and Eames,

et al. (1962), in each of which a different interpretation of correlation of the planktonic zones with the European stages was proposed.

The succession in the Heywood Bore nevertheless has been correlated tentatively with the European stages by accepting the stratigraphic ranges of Caribbean planktonic species as interpreted by Stainforth (1960, distribution chart, p. 221). The base of the Aquitanian, regarded as defining the Oligocene—Miocene boundary, is placed between cores AD and AE. This interpretation may be modified, however, as the pelagic Foraminifera of the European Tertiary are more thoroughly studied, and further data are accumulated in other parts of the world.

CORRELATION WITH THE MURRAY BASIN IN SOUTH AUSTRALIA

The northern continuation of the Otway Basin in Victoria and South Australia is known as the Murray Basin. Ludbrook (1961, tables 10 and 11), working with both outcrop and subsurface samples, published the ranges of stratigraphically important benthonic and planktonic Foraminifera in the South Australian portion of the Murray Basin in terms of the stratigraphic units previously established for this area (Ludbrook, 1957).

The association of *Orbulina universa*, "*Biorbulina*" *bilobata*, "*Candorbulina*" *universa*, "*Porticulasphaera*" *glomerosa glomerosa*, and "*P.*" *glomerosa curva* in the lower part of Ludbrook's Pata limestone correlates this part of the sequence with the upper part of the *Globigerinatella insueta* Zone or base of the *Globorotalia fohsi barisanensis* Zone (Bolli, 1957) of the Caribbean, and with core AA of the Heywood Bore. The presence of *Cibicides victoriensis* in core AA and in the Pata limestone strengthens the correlation.

The lower part of the Heywood marl and the Nelson formation appear to correlate with at least the upper part of Ludbrook's Ettrick formation, but some discrepancies make this and further correlations uncertain. According to Ludbrook (1961, tables 10 and 11), *Astrononion centroplax*, *Globigerina linaperta*, and *Gümbelina rugosa* occur together in the lower part of the Ettrick formation. This is not in agreement with the ranges of these species given by Carter (1964, table 4) in defining his Faunal Units (see section on "Correlation with subdivisions of the Victorian Tertiary"). Ludbrook (1961, table 11) showed *Globigerinoides ruber* making its appearance earlier than either *Globigerina ciperoensis* or *Glo-*

bigerinoides trilobus in the Murray Basin, contrary to the records from the Caribbean (Bolli, 1957, p. 99), from Lakes Entrance (Jenkins, 1960, p. 347), and from the Aire district in western Victoria (Carter, 1958b, p. 29), as well as from other areas throughout the world. Finally, the occurrences of *Globigerina bulloides* in and below the Pata limestone (Ludbrook, 1961, table 11) probably refer to another species, as *G. bulloides* does not appear until much later (Blow, 1959, p. 175).

Unfortunately, no descriptions and only a few illustrations of the Foraminifera were published by Ludbrook (1961), so that the identifications cannot be checked. Misinterpretation of the stratigraphic position of certain of her samples, which included both outcrop and subsurface samples from over a wide area, may have also contributed to the discrepancies mentioned.

CORRELATION WITH INDO-PACIFIC LETTER CLASSIFICATION

The Indo-Pacific "Letter Classification" was originally set up by van der Vlerk and Umbgrove (1927) on the basis of larger Foraminifera. To attempt to correlate this classification with the Caribbean planktonic zones, it is necessary to use samples containing larger Foraminifera and planktonic Foraminifera in association—the former to give the age in terms of the "Letter Classification", and the latter to enable correlation with the Caribbean zonation to be made. Three instances involving this approach have been published. All are concerned with the correlation of the *Globigerinatella insueta*/*Globigerinoides bisphericus* Subzone (Blow, 1959), or more specifically, the initial appearance of *Orbulina suturalis*, near the top of this subzone.

LeRoy (1958, p. 506) recorded the first appearance of *Candorbulina universa* (= *Orbulina suturalis*) near the top of the Telisa formation in Central Sumatra and regarded this point as marking the division between Tertiary *e* and Tertiary *f*. However, Glaessner (1959) in his correlation chart (table 1), included most of the Telisa in Tertiary *f*, thus placing the first appearance of *O. suturalis* at some time during Tertiary *f*, rather than at the beginning, as suggested by LeRoy.

Todd, *et al.* (1954) recognized the *Globigerinatella insueta*/*Globigerinoides bisphericus* Subzone in the Fina-Sisu formation on Saipan and correlated it with beds containing an assemblage of Tertiary *e* larger Foraminifera. Glaessner (1959, p. 58) discussed this occurrence and sug-

gested a possible alternative interpretation of the field evidence. He correlated the *Globigerinatella insueta*/*Globigerinoides bisphericus* Subzone with Tertiary *f*. The findings of Cole, *et al.* (1960) on Yap, in the light of this reinterpretation, added support to Glaessner's conclusion, as under the original interpretation of Todd, *et al.* (1954) the question of conflicting age determinations on Yap using larger and smaller Foraminifera could not be resolved.

It thus appears, from the available evidence, that the *Globigerinatella insueta*/*Globigerinoides bisphericus* Subzone of the Caribbean correlates with at least part of the Tertiary *f* Stage of the Indo-Pacific region. Correlation of other planktonic zones with the "Letter Classification" in the Indo-Pacific will be an important test of this conclusion.

PALEOECOLOGY

ENVIRONMENT OF DEPOSITION OF GLENELG GROUP SEDIMENTS

The Nelson formation represents the initiation of true marine sedimentation in the Tertiary section encountered in Heywood No. 10 Bore. The general lithologic aspect (coarse calcareous sandstones; carbonaceous siltstones) indicates fluctuating marginal conditions in a near-shore environment. An unfavourable bottom environment is suggested by the paucity of the fauna with its accompanying pyritization, but the appearance of a few pelagic Foraminifera (Table 3) in the upper parts of the formation demonstrates that access to the open sea had been established by this time.

Uniform, normal marine deposition of the Gambier limestone in an open-sea environment is indicated by relatively uniform lithology and abundant pelagic Foraminifera throughout this formation (Table 3).

Most of the Heywood marl is characterized by an abundance of simple arenaceous forms, miliolids, and coarsely perforate genera such as *Cibicides* (Table 3), an association which suggests an inner continental shelf environment (depth between 20 and 60 m.). Abundant remains of echinoids, most of which are shelf dwellers (Hyman, 1955, p. 569), also support this hypothesis. The fauna from core AH is deficient in these inner shelf indicators, and this part of the Heywood marl was probably deposited in deeper water than the overlying part.

Deeper water is suggested for the Portland limestone by the absence of miliolids and echinoid fragments, and the rare occurrence of arenaceous

Table 3.- Percentages of various foraminiferal groups within core samples from the Heywood Bore

Core	Arenaceous	Mollusks	Polymorphinids	Other benthonics	Pelagics	Total number of specimens counted
AA	2	-	-	38	60	1867
AB	4	-	10	37	49	2170
AC	12	14.5	-	25.5	48	1174
AD	13	16	0.5	21.5	49	1926
AE	27	17.5	2	28	25.5	1115
AF	11	8	1.5	33	46.5	1761
AG	11.5	18	8	15.5	47	2076
AH	1	-	2.5	43.5	53	1426
AI(1)	-	7	-	40	53	15
AI(2)	100	-	-	-	-	3
AJ(2)	92	-	-	8	-	37

Foraminifera (Table 3). The environment, however, was still probably on the shelf, as shown by the presence of *Camerina complanata* in this member. Cole (1959, table 1) stated that *Operculina bartschi* (= *Camerina complanata*; see Cole, 1961, pp. 120-122) occurs commonly in the Recent Philippine and adjacent seas between depths of 19 and 52 fathoms (35-95 m.), corresponding to a position on the outer continental shelf. Reduction in the amount of detritus entering the environment, correlated possibly with a more distant shoreline, is expressed in the increased proportion of soluble carbonate in the Portland limestone.

Polymorphinids have an irregular distribution throughout the Gambier limestone. The ecological implications of this are not apparent.

The overall picture is one of a typical marine transgression, beginning in Nelson time, with the sea progressively deepening, and the shoreline shifting away from the area during the time of deposition of the Gambier limestone.

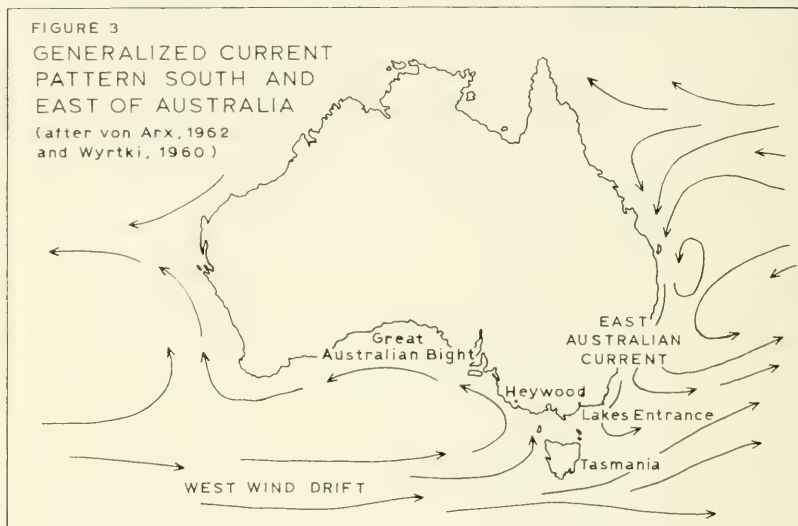
INFLUENCE OF OCEANIC CIRCULATION ON PLANKTONIC FAUNA

As mentioned above, Jenkins (1960) noted differences in the Tertiary planktonic faunas of the Caribbean region and of the Lakes Entrance Oil Shaft in eastern Victoria. Differences have also been recognized in the Tertiary planktonic assemblages of eastern Victoria, as exemplified in the Lakes Entrance Oil Shaft, and those of western Victoria and southeastern South Australia, as recorded by Ludbrook (1961) and in the present study.

Planktonic Foraminifera typical of the present tropical and subtropical oceans are found in the eastern Victorian sequence, whereas these warm-water elements are absent or rare in western Victoria and southeastern South Australia. Important points of difference are as follows: (1) the presence of a number of species of *Globorotalia* s.s. in the eastern Victorian Tertiaries contrasted with the complete absence of this genus in South Australia (Ludbrook, 1961, table 11) and its extreme scarcity in the Heywood section; (2) the dominance of *Globigerina* species throughout most of the section in the western area, with other genera (except *Orbulina*) forming only a relatively small proportion of the total planktonic population; and (3) the rarity or absence of *Globoquadrina debiscens* (and absence of other species of this genus) from the western area in the lower part of its range as recorded by Jenkins (1960, text fig. 2) in the Lakes Entrance Oil Shaft in eastern Victoria.

An Oligocene—Miocene oceanic circulation, similar to that existing today in the southern Australian region, may have been responsible for the faunal differences noted above. Figure 3, based on data from Wyrтки (1960, fig. 13) and von Arx (1962, fig. 6-20), shows the present generalized current pattern in this region.

The warm East Australian Current moves southward (Fig. 3) along the eastern coast of Australia before turning eastward and northeastward away from the continent. The most southerly point reached by the current before turning depends largely on the time of year (Wyrтки, 1960, fig. 15). During summer, its influence may extend as far south as latitude 42°S (Newell, 1961), thus affecting part of the eastern Victorian coast. Recent planktonic Foraminifera obtained within the area influenced by the current include forms found only in tropical and subtropical waters (Brady, 1884; Whitelegge, 1889; Jensen, 1904; Goddard, 1907; Goddard and Jensen, 1907; Chapman, 1941).



The western Victorian coast is influenced by a branch of the West Wind Drift (Fig. 3) deflected northward along the west coast of Tasmania and continuing westward through the Great Australian Bight. This current is made up of cool waters (Rochford, 1962, fig. 17 and table 1), although in summer, subtropical water from the southern Indian Ocean moves eastward with the West Wind Drift and the temperature is slightly raised. Little data are available on the planktonic Foraminifera occurring within the area influenced by this current off the southern coast of Australia. No tropical or subtropical forms have been recorded in published lists of planktonic Foraminifera from this area (Brady, 1884; Chapman, 1907b; McKenzie, 1962). Further work is needed to confirm this, especially in the light of the statement by Newell (1961, p. 9) that strandings of subtropical and tropical fauna are regular occurrences along the west coast of Tasmania during the summer.

On the available evidence, however, it seems reasonable to conclude that tropical and subtropical forms, carried by the warm East Australian Current, will be found in a zone along the eastern Australian coast, extending an unknown distance westward along the eastern part of the Victorian coast. The western shores of the State, however, influenced by the West Wind Drift, will harbor a cooler water fauna. Similar faunal

separation into warm-and cool-water assemblages by water masses of different temperature has been observed in the Recent planktonic Foraminifera of the western North Atlantic (Bé, 1959; Cifelli, 1962), the western South Atlantic (Boltovskoy, 1962), and the seas surrounding Japan (Asano, 1957).

In Oligocene—Miocene times, it is postulated that a differentiation of the planktonic fauna took place in a similar way in southeastern Australia through the influence of a current pattern not unlike that existing today. During the time of maximum transgression, represented in the Heywood Bore by the Portland limestone, it is possible that the influence of the warm East Australian Current extended farther westward than at present. This allowed occasional warm-water forms to enter the area normally affected by the West Wind Drift waters in detached eddies, a mechanism postulated for the entry of warm-water faunas into the shelf regions of the western North Atlantic by Cifelli (1962, p. 212). By this means, a few planktonic Foraminifera restricted to warm waters, such as *Globorotalia menardii*, may have occasionally entered the Portland Sunklands and become associated in the bottom sediments with the typical indigenous cooler water forms.

Globoquadrina debiscens by its faunal association was seemingly a warm-water form but probably had a greater tolerance for lower temperature than *Globorotalia menardii*. *Globoquadrina debiscens* could thus still exist and be able to penetrate westward into the cooler water area during the time of maximum transgression of the Portland sea, whereas *Globorotalia menardii* was restricted by temperature requirements to areas in which the temperature could be no lower than that of the present East Australian Current in its most southerly extension. The rarity of *Globoquadrina debiscens* in the Heywood marl is the result of the influence of the East Australian Current not extending as far west in the earlier stages of the transgression, so that this species rarely reached the Heywood area.

Orbulina universa is regarded by some authors (e.g., Bé, 1959) as a warm-water species. Stone (1956), working with samples from the western Atlantic, concluded that this species was abundant at temperatures of 54°F (12.2°C.) and above. The present-day temperature of the northern edge of the West Wind Drift in the area south of Australia is about 15.5°C. (Rochford, 1962, table 1) and becomes higher as the coastline is approached. Therefore, *O. universa* could survive, at least, in the northern fringes of this current. Under such conditions, the abundance of *Orbulina* in core AA from the Heywood Bore would not be unexpected.

At some point off the coast of eastern Victoria, there is an area where the East Australian Current and the West Wind Drift come into contact. Chapman (1941, p. 149) drew attention to the presence of small calcite crystals in the bottom sediments of eastern Bass Strait in this vicinity. He attributed the formation of these crystals to "supersaturated" warmer waters being cooled by admixture with cooler waters, thus causing the excess calcium carbonate to be precipitated as a shower of small crystals. Although his explanation was incorrect as an increase, rather than a decrease, in temperature, or an increase in salinity (among other factors) causes the precipitation of calcium carbonate from sea water (Cloud, 1962, p. 102), the conclusion that accumulation of small calcite crystals on the sea floor occurs in the vicinity of the meeting of the two currents was correct. Chapman (1941, p. 149) also noted that the same type of calcite crystals were obtained in the washings of the ". . . fossiliferous marls of Lower Miocene age . . ." in eastern Victoria. This supports the idea that the Oligocene—Miocene current pattern was similar to that existing today, since no calcite crystals have been observed in washings of sediments from western Victoria.

SYSTEMATIC DESCRIPTIONS

This section is divided into three parts. The first part lists by families, according to the classification of Glaessner (1945), those benthonic species which have been recorded previously from Australia or the Indo-Pacific region and for which adequate descriptions are available. To avoid needless listings of synonymies, a single reference is given for each species and its occurrence in the Heywood Bore is indicated by the core designation after the reference. Benthonic species on which taxonomic or ecologic observations have been made are grouped by families and discussed in the second part. The third part consists of a systematic treatment of the planktonic forms. Although most of these forms are abundant in all cores, a qualitative assessment of their relative frequencies in terms of the total planktonic population is included in the discussion of these species.

Relative frequencies and occurrences of the benthonic species are summarized in Table 4. The relative frequencies of specimens in a sample of standard size were assigned as shown in Table 4.

Ranges of the planktonic species in the Heywood Bore are shown on the correlation chart (Fig. 2).

Species

Cores

	AA	AB	AC	AD	AE	AF	AG	AH	AI(1)	AI(2)	AJ(2)
<i>Cyclammima incisa</i>	R			R		R				R	C
<i>Cyclammima longicompresa</i>										R	C
<i>Cyclammima paupera</i>					R					R	F
<i>Cyclammima rotundata</i>	R			R	R						
<i>Cyclammima communis</i>	R	R								R	
<i>Dentalina consobrina</i>	S			R		R					
<i>Dentalina obliquestrata</i>											
<i>Discorbinella biconcava</i>											
<i>Discorbis balcombensis</i>	R	R	S	C			R				
<i>Ehrenbergina osbornei</i>		F									
<i>Elphidium crespinae</i>								R			
<i>Elphidium parri</i>	F	R									
<i>Eponides repandus</i>		A	R	C	C	F	A	S			
<i>Fissurina bifida</i>		C		R	R	R	S				
<i>Fissurina circularis</i>	C	C	S	S	R	C	R	F			
<i>Fissurina lacunata</i>					R	A	S	C			
<i>Fissurina lagenoides</i>				R							
<i>Fissurina pacifica</i>	C	R	R	R		R					
<i>Frondicularia inaequalis</i>	R			R							
<i>Gaudryina (Gaudryina) collinsi</i>			R	C		R					
<i>Gaudryna (Pseudogaudryina) crespinae</i>	R	S	F	A	C	A	A	R			
<i>Gaudryina (Gaudryina) heywoodensis</i>			R	A	A	A	F	S			
<i>Glandulina laevigata</i>	R			R	S	S	A	S			
<i>Globulina gibba</i>		S		R		R	A	S			
<i>Guttulina irregularis</i>		F			S						
<i>Guttulina pacifica</i>		S		S			A	S			
<i>Guttulina problema</i>											
<i>Guttulina silvestrii</i>		S					S	R			
<i>Guttulina spicaeformis</i>		S					C	R			
<i>Guttulina yabei</i>		C		R	C	R					
<i>Gyroidinoides allani</i>							R				
<i>Gyroidinoides zelandicus</i>							R	C			
<i>Heronallenia lingulata</i>			R	R		R	R	S			
<i>Heronallenia parri</i>				R		R	R	F			

Species

Cores

	AA	AB	AC	AD	AE	AF	AG	AH	AI(1)	AI(2)	AJ(2)
Hopkinsina mioindex		S									
Lagena acuticosta	S	S				F		C			
Lagena favosopunctata	F	S		F	R	S	R	C			
Lagena semistriata				S		R		R			
Lagena striata	R						S				
Lagena sulcata	S			R		R					
Lagenonodosaria scalaris	A	A				S					
Lenticulina crepidula	S	F					C				
Marginulina tenuis				S							
Miliolinella oblonga		R	S	R	R	R	S	C			
Mississippiina concentrica				R							
Nodosaria hispida	S			R	S	S	R	R	R		
Nodosaria insecta		R		F	R	F	F	R			
Nodosaria obliqua											
Nodosaria pyrula	R	R		R	S						
Nodosaria raphanistrum	R			R		R					
Nodosaria vertebralis	R	F									
Nonion victoriensis	C										
Pseudoclavulina bradyana				F							
Pseudoclavulina rudis					A	S	A	R			
Pullenia bulloides					R	F	F	C			
Pullenia quinqueloba						R	R				
Pyrgo bulloides	F										
Pyrgo inornata		S		S	S	R	F				
Pyrgo sarsi		R	C	C	C	F	A				
Pyrgo subspheerica				R							
Pyrgo cylindroides											
Pyrgulina fusiformis					S	R	C	S			
Quinqueloculina cuvieriana				R	S	R					
Quinqueloculina lamarckiana			F	F	S	S					
Quinqueloculina polygona				C	F						
Quinqueloculina vulgaris			A	A	A	S	A				
Reussella simplex				R		C		R	R?		
Robulus alatolimbatus	S	C	S	S	C	R		S			

Species	Cores											
	AA	AB	AC	AD	AE	AF	AG	AH	AI(1)	AI(2)	AJ(2)	
<i>Robulus cultratus</i>				S	S	R						
<i>Robulus gyrosalpinx</i>		R			S			R				
<i>Robulus inornatus</i>	R	C		F	S	F	F	F				
<i>Rotalia scabricula</i>						F	S					
<i>Rosalina bertheloti</i>	A	R	S	C		C	R					
<i>Sigmoidella elegantissima</i>		A			R	S						
<i>Sigmoidella kagaensis</i>		C										
<i>Sigmollina victoriensis</i>					F	R						
<i>Sigmolopsis compressa</i>			R	S	R							
<i>Sigmolopsis chapmani</i>			F	R		R	A	F				
<i>Sigmomorphina chapmani</i>												
<i>Sigmomorphina subregularis</i>		C										
<i>Siphonina australis</i>	C	R	R	S		F	F	A	R?			
<i>Sphaeroidina bulloides</i>	C	A	S	R	R	C	R					
<i>Spirillina vivipara</i>				S		R	A					
<i>Spiroloculina disparilis</i>					C	S						
<i>Spiroloculina tenuiseptata</i>			F									
<i>Textularia barnetti</i>	S	F	A	A	S	A	A					
<i>Textularia fistulosa</i>			S	R								
<i>Textularia porrecta</i>	C	A	A	R	S							
<i>Textularia sagittula</i>	C	A	F	R		S	F					
<i>Trifarina bradyi</i>		R				R	F	F				
<i>Triloculina brochita</i>			S	A	C	C	C					
<i>Triloculina collinsi</i>					S		R					
<i>Triloculina trigonula</i>			C	S	F	C	C					
<i>Uvigerina nitidula</i>		R										
<i>Uvigerina proboscidea</i>				S				A				

Hypotypes and all figured specimens will be deposited in the Collections of the Museum of the Geological Survey of Victoria, Melbourne, Australia.

A. BENTHONIC SPECIES PREVIOUSLY RECORDED FROM THE
INDO-PACIFIC AND AUSTRALIAN REGIONS

FAMILY AMMODISCIDAE

Ammodiscus parri Crespin (Crespin, 1950, pp. 71, 72, pl. 10, fig. 2)—AD.

FAMILY LITUOLIDAE

Cyclammina incisa (Stache) (Crespin, 1950, p. 72, pl. 10, fig. 3)—AA, AD, AF, AI(2), AJ(2).

C. longicompressa Chapman and Crespin (Chapman and Crespin, 1930, p. 97, pl. 5, figs. 3, 4)—AI(2), AJ(2).

C. paupera Chapman (Crespin, 1950, p. 72, pl. 10, fig. 4)—AE, AJ(2).

C. rotundata Chapman and Crespin (Crespin, 1950, p. 72, pl. 10, figs. 5a, b)—AA, AD, AE, AI(2).

FAMILY TEXTULARIIDAE

Textularia porrecta (Brady) (Heron-Allen and Earland, 1924, p. 137)—AA-AD. Pl. 11, fig. 7

T. sagittula Defrance (Heron-Allen and Earland, 1924, p. 136)—AA-AG. Pl. 11, fig. 8

FAMILY TROCHAMMINIDAE

Ammosphaeroidina sphaeroidiniformis (Brady) (*Haplophragmium sphaeroidiniforme* Brady, in Chapman, 1907a, pp. 24, 25, pl. 3, figs. 50, 51)—AC, AE.

FAMILY VERNEUILINIDAE

Gaudryina (*Gaudryina*) *collinsi* Cushman (Cushman, 1936, pp. 8, 9, pl. 2, figs. 2a, b)—AC, AD, AF.

G. (*Pseudogaudryina*) *crespiniae* Cushman (Cushman, 1936, p. 14, pl. 2, figs. 15a, b)—AA-AH. Pl. 11, figs. 4, 11

FAMILY MILIOLIDAE

Quinqueloculina cuvieriana d'Orbigny (*Miliolina cuvieriana* d'Orbigny, in Chapman, 1907a, p. 19, pl. 2, fig. 33)—AC-AF.

Q. lamarckiana d'Orbigny (*Q.* aff. *lamarckiana* d'Orbigny, in LeRoy, 1941, p. 71, pl. 5, figs. 5, 6)—AD, AE.

Q. polygona d'Orbigny (*Miliolina polygona* d'Orbigny, in Chapman, 1907a, p. 18, pl. 2, fig. 29)—AD, AF.

- Q. vulgaris* d'Orbigny (*Miliolina vulgaris* d'Orbigny, in Chapman, 1907a, pp. 18, 19, pl. 2, fig. 32)—AC-AG, ?AI(1).
Triloculina collinsi Carter (Carter, 1964, pp. 59, 60, pl. 1, figs. 5, 6)—AE, AG.
Pyrgo sarsi (Schlumberger) (Carter, 1964, p. 61, pl. 1, figs. 10, 11)—AC-AG.
P. subsphaerica (d'Orbigny) (*P. subspherica* (d'Orbigny), in LeRoy, 1941, p. 22, pl. 1, figs. 33, 34)—AD.
Miliolinella oblonga (Montagu) (*Miliolina oblonga* Montagu, in Chapman, 1907a, p. 17, pl. 2, fig. 26)—AD.
Biloculinella globula (Bornemann) (*Biloculina globulus* Bornemann, in Chapman, 1907a, pp. 15, 16, pl. 1, figs. 17, 18)—AC-AG.
Spiroloculina disparilis Terquem (Cushman and Todd, 1944, pp. 35, 36, pl. 5, figs. 29-31)—AD, AF.
Sigmoilina victoriensis Cushman (Cushman, 1946b, p. 103)—AE, AF.
Sigmoilopsis chapmani (Cushman) (*Sigmoilina chapmani* Cushman, in Cushman, 1946a, p. 31, pl. 5, figs. 7-9)—AC, AD. Pl. 11, fig. 5

FAMILY OPHTHALMIDIIDAE

- Cornuspira crassisepta* Brady (Chapman, 1907a, p. 22, pl. 2, fig. 45)—AD, AF.
C. foliacea (Philippi) (Chapman, 1907a, p. 24, pl. 3, fig. 48)—AC-AG.
C. involvens (Reuss) (Chapman, 1907a, pp. 22, 23, pl. 2, fig. 46)—AE, AG.

FAMILY LAGENIDAE

- Nodosaria hispida* d'Orbigny (Chapman and Parr, 1926, p. 379, pl. 18, fig. 25)—AA, AD.
N. insecta Schwager (LeRoy, 1944, p. 80, pl. 1, fig. 18)—AB, AD-AI(1).
N. obliqua (Linné) (Heron-Allen and Earland, 1924, p. 155)—AE-AH.
N. pyrula d'Orbigny (Heron-Allen and Earland, 1924, p. 153)—AA.
N. raphanistrum (Linné) (Chapman and Parr, 1926, pp. 380, 381, pl. 18, fig. 29)—AA, AB, AD, AE.
N. vertebralis (Batsch) (Chapman and Parr, 1926, p. 380, pl. 18, fig. 28)—AA, AB, AD, AF.
Dentalina communis (d'Orbigny) (*Nodosaria* (*Dentalina*) *communis* (d'Orbigny), in Chapman and Parr, 1926, p. 381, pl. 18, fig. 31)—AA, AB.

- D. consobrina* d'Orbigny (*Nodosaria* (*Dentalina*) *consobrina* (d'Orbigny), in Chapman and Parr, 1926, p. 381, pl. 18, fig. 33)—AA, AF.
- D. obliquestriata* Reuss (Todd, 1957, p. 267 (tab.), p. 270 (tab.), pl. 65, figs. 17, 18)—AD, AF.
- Lagena acuticosta* Reuss (LeRoy, 1944, p. 22, pl. 1, fig. 11)—AA, AB, AF, AH.
- L. favosopunctata* Brady (Chapman and Parr, 1926, p. 376, pl. 17, fig. 10)—AA, AB, AD-AH.
- L. semistriata* (Williamson) (Chapman and Parr, 1926, p. 374, pl. 17, fig. 19)—AD, AF, AH.
- L. striata* (d'Orbigny) (Chapman and Parr, 1926, pp. 374, 375, pl. 17, fig. 5)—AA, AG, AH.
- L. sulcata* (Walker and Jacob) (Chapman and Parr, 1926, p. 375, pl. 17, fig. 6)—AA, AD, AF.
- Fissurina bifida* (Heron-Allen and Earland) (*Lagena orbignyana* var. *bifida* nov., in Heron-Allen and Earland, 1924, p. 152, pl. 9, figs. 46-50)—AB, AD-AG.
- F. circularis* Todd (Cushman, Todd and Post, 1954, p. 351, pl. 87, fig. 27)—AA-AH.
- F. lacunata* (Burrows and Holland) (*Lagena lacunata* Burrows and Holland, in Chapman and Parr, 1926, p. 378, pl. 17, fig. 18)—AE-AH.
- F. lagenoides* (Williamson) (Parr, 1947, p. 128, pl. 6, fig. 15)—AD.
- F. pacifica* Parr (Parr, 1950, p. 314, pl. 9, figs. 10a, b)—AA-AD, AF.
- Marginulina tenuis* Bornemann (*Cristellaria tenuis* (Bornemann), in Brady, 1884, pl. 66, figs. 21-23)—AA.
- Lenticulina crepidula* (Fichtel and Moll) (*Cristellaria crepidula* (Fichtel and Moll), in Chapman and Parr, 1926, pp. 387, 388, pl. 20, fig. 57)—AB, AG.
- Robulus alatolimbatus* (Gümbel) (Todd, 1957, p. 266 (tab.), pl. 64, figs. 24a, b)—AA-AF, AH.
- R. cultratus* Montfort (*Cristellaria cultrata* (Montfort), in Chapman and Parr, 1926, p. 390, pl. 21, fig. 68)—AD-AF.
- R. gyroscalprus* (Stache) (Hornibrook, 1961, p. 36, pl. 5, fig. 67)—AB, AE, AH.
- R. inornatus* (d'Orbigny) (*R. aff. inornatus* (d'Orbigny), in LeRoy, 1941, p. 25, pl. 3, figs. 62, 63)—AA, AB, AD-AH.
- Frondicularia inaequalis* Costa (Chapman and Parr, 1926, p. 385, pl. 20, fig. 50)—AA, AD.

FAMILY POLYMORPHINIDAE

- Guttulina irregularis* (d'Orbigny) (Cushman and Ozawa, 1930, pp. 25-27, pl. 3, figs. 4, 5; pl. 7, figs. 1, 2)—AB, AD, AF-AH.
- G. pacifica* (Cushman and Ozawa) (*G. (Sigmoidea) pacifica* (Cushman and Ozawa), in Cushman and Ozawa, 1930, p. 50, pl. 37, figs. 3-5)—AB, AF.
- G. silvestrii* Cushman and Ozawa (*G. (Sigmoidea) silvestrii* Cushman and Ozawa, in Cushman and Ozawa, 1930, p. 51, pl. 37, figs. 6, 7)—AB.
- G. yabei* Cushman and Ozawa (Cushman and Ozawa, 1930, pp. 30, 31, pl. 4, figs. 6, 7)—AB, AD, AF-AH.
- Pyrulina cylindroides* (Roemer) (Cushman and Ozawa, 1930, pp. 56, 57, pl. 14, figs. 1-5)—AG.
- P. fusiformis* (Roemer) (Cushman and Ozawa, 1930, pp. 54-56, pl. 13, figs. 3-8)—AD-AH.
- Globulina gibba* (d'Orbigny) (Cushman and Ozawa, 1930, pp. 60-64, pl. 16, figs. 1-4)—AB, AE, AG, AH.
- Sigmomorphina chapmani* (Heron-Allen and Earland) (*Polymorphina chapmani* Heron-Allen and Earland, in Heron-Allen and Earland, 1924, p. 163, pl. 10, figs. 60-63)—AF-AH. Pl. 12, fig. 3
- S. subregularis* Howchin and Parr (Howchin and Parr, 1938, p. 308, pl. 18, figs. 2, 11)—AB.
- Sigmoidella elegantissima* (Parker and Jones) (Cushman and Ozawa, 1930, pp. 140, 141, pl. 39, figs. 1a-c)—AB, AE, AF. Pl. 12, fig. 6
- Glandulina laevigata* (d'Orbigny) (Cushman and Ozawa, 1930, p. 143, pl. 40, figs. 1a, b)—AA, AD-AH.

FAMILY BULIMINIDAE

- Buliminella spicata* (Cushman and Parker) (*Buliminella madagascariensis* (d'Orbigny) var. *spicata* Cushman and Parker, in Cushman, 1942, p. 8, pl. 3, figs. 5, 6)—AC-AG.
- Reussella simplex* (Cushman) (Cushman, 1945, p. 40, pl. 7, figs. 5a, b)—AD, AF, AH.
- Uvigerina nitidula* Schwager (Todd, 1957, p. 273 (tab.), pl. 73, figs. 6a, b)—AB.
- Hopkinsina mioindex* Finlay (Finlay, 1947, p. 282, pl. 5, figs. 80-82)—AB.
- Trifarina bradyi* Cushman (Chapman and Parr, 1926, p. 386, pl. 20, fig. 52)—AB, AF-AH.

Bolivina robusta Brady (Cushman, 1937b, pp. 131-133, pl. 17, figs. 1-4)—AA.

B. sublobata Cushman (Cushman, 1936, p. 52, pl. 7, figs. 16a, b)—AC, AD, AF, AG.

FAMILY CASSIDULINIDAE

Cassidulina laevigata d'Orbigny (Heron-Allen and Earland, 1924, p. 145)—AB.

C. subglobosa Brady (Heron-Allen and Earland, 1924, p. 146)—AB, AF, AH, AI(1).

Ehrenbergina osbornei Finlay (Finlay, 1939, p. 322, pl. 28, figs. 120, 123, 124)—AB.

FAMILY CHILOSTOMELLIDAE

Pullenia quinqueloba (Reuss) (Carter, 1958b, pp. 32, 33, pl. 2, figs. 8, 9)—AF-AH.

Sphaeroidina bulloides d'Orbigny (Cushman and Todd, 1949, pp. 13-15, pl. 3, figs. 8-11)—AA, AB, AD-AH, ?AI(1).

FAMILY SPIRILLINIDAE

Spirillina vivipara Ehrenberg (Carter, 1958b, pp. 39, 40, pl. 4, figs. 32, 33)—AC-AE, AG.

FAMILY DISCORBIDAE

Discorbis balcombensis Chapman, Parr and Collins (Chapman, Parr and Collins, 1934, pp. 562, 563, pl. 8, figs. 10a-c)—AA, AC, AD, AG.

Discorbinella biconcava (Parker and Jones) (Carter, 1964, pp. 86, 87, pl. 5, fig. 97-100)—AB.

Heronallenia lingulata (Burrows and Holland) (Carter, 1958b, pp. 42, 43, pl. 5, figs. 40-42)—AC, AD, AF, AH.

H. parri Carter (Carter, 1958b, pp. 43, 44, pl. 5, figs. 43-45)—AD, AF-AH.

Gyroidinoides zelandicus (Finlay) (Hornibrook, 1961, p. 113, pl. 16, figs. 339, 344)—AB, AG, AH.

Alabamina tenuimarginata (Chapman, Parr and Collins) (Carter, 1964, p. 114, pl. 11, figs. 220-222)—AB.

Siphonina australis Cushman (Carter, 1964, p. 93, pl. 7, figs. 127-129)—AA-AD, AF.

Cibicides brevoralis Carter (Carter, 1958b, pp. 47-49, pl. 6, figs. 54-56)—AB, AD-AF.

C. subbaidingerii Parr (Carter, 1964, p. 95, pl. 8, figs. 145-147)—AA.
Anomalina macraglabra Finlay (Carter, 1964, pp. 99, 100, pl. 8, figs. 151-153)—AA-AI(1).

Anomalinoides procolligera Carter (Carter, 1958b, pp. 59, 60, pl. 6, figs. 60-63)—AB, AD, AF-AH.

FAMILY NONIONIDAE

Nonion victoriensis Cushman (Carter, 1964, pp. 109, 110, pl. 10, figs. 201, 202)—AA.

Astrononion australis Cushman and Edwards (Carter, 1964, p. 111, pl. 11, fig. 207)—AC, AD, AG.

A. centroplax Carter (Carter, 1958b, pp. 61-63, pl. 9, figs. 95-97)—AD-AG.

A. obesus Carter (Carter, 1964, p. 112, pl. 10, figs. 205-206)—AB.

Elphidium crespinae Cushman (Carter, 1963, p. 121, pl. 12, figs. 240, 241)—AH.

E. parri Cushman (Carter, 1964, p. 122, pl. 13, figs. 250, 251)—AA, AB.

FAMILY ROTALIIDAE

Rotalia scabricula (Chapman) (Carter, 1964, p. 119, pl. 12, figs. 234-239; pl. 16, figs. 285-287)—AF, AG.

B. OBSERVATIONS ON OTHER BENTHONIC SPECIES

Family TEXTULARIIDAE

Genus TEXTULARIA Defrance, 1824

Textularia barnetti Bermudez

1949. *Textularia barnetti* Bermudez, Cushman Lab. Foram. Res., Sp. Pub. 25, p. 58, pl. 2, figs. 1, 2.

Chapman (1907, p. 26, pl. 3, fig. 55) recorded this form from the Balcombian of the Port Phillip area under the name *T. abbreviata* d'Orbigny. The Heywood specimens, Chapman's figured specimen, and the type of *T. barnetti*, however, have a rounded cross-section, and fewer and higher chambers than *T. abbreviata*, in which the test has an angular margin and consists of more chambers.

Occurrence.—AC.

Textularia fistulosa (Brady)

1884. *Textularia sagittula* Defrance var. *fistulosa* Brady, Rep. Challenger Exped., Zool., pt. 22, vol. 9, p. 362, pl. 42, figs. 19-22.

This form has been separated from *T. sagittula* Defrance, which also occurs in the Heywood material, as a distinct species. There are no intergrading forms between the two. The "tubulated projections" of Brady (1884, p. 362), accompanied nearly always by ridgelike tubercles along each chamber transverse to the direction of growth, and often a coarser texture, distinguish *T. fistulosa* from *T. sagittula*, which has a smooth unornamented test (Pl. 11, fig. 8). The number and arrangement of the "tubulated projections" exhibit the same variability described by Brady (1884).

Occurrence.—AA-AG.

Family VERNEULINIDAE

Genus **GAUDRYINA** d'Orbigny, 1839, emend. Bowen, 1955

Subgenus **GAUDRYINA** d'Orbigny, 1839

Gaudryina (Gaudryina) heywoodensis Reed, nom. nov. Pl. 11, figs. 1, 13

1936. *Dorothia parri* Cushman, Cushman Lab. Foram. Res., Sp. Pub. 6, pp. 29, 30, pl. 4, figs. 19a, b. (*Non Gaudryina (Pseudogaudryina) parri* Cushman, 1936, Cushman Lab. Foram. Res., Sp. Pub. 6, p. 15, pl. 2, figs. 11a, b).

Description.—

Test large, broadly oval in front view, circular in end view, earliest stage with four or five chambers, then triserial, adult biserial; chambers comparatively few, two pairs making up the larger part of the adult test, distinct, inflated, high as broad, somewhat overlapping; sutures fairly distinct, lightly depressed, horizontal or slightly oblique in adult; wall coarsely arenaceous, surface somewhat roughened; aperture elongate, low. Length 1.60 mm.; diameter 1.10 mm.

Holotype.—From the Miocene of Campbell's Point, Lake Connemara near Geelong, Victoria, Australia (Cushman Coll., No. 19173).

Remarks.—Bowen (1955) gave adequate reasons for placing the genus *Dorothia* Plummer, 1931 in synonymy with that of *Gaudryina* d'Orbigny, 1839. The original distinction was based on the presence of a "... youthful trochoid spire composed of more than three chambers in the first whorl ..." (Plummer, 1931, p. 130) in *Dorothia*, which later became triserial and then biserial, as in *Gaudryina*. Bowen's conclusion is supported by the present study of *G. heywoodensis*, in which the number of chambers in the initial whorl seems to vary from four to three. The determination of this number is difficult, in that a section ground not quite at right angles to the axis of growth will appear to show more than three chambers in the whorl. Misinterpretation of such sections may have led to errors in the past.

It is thus proposed to name the present form *Gaudryina (Gaudryina) heywoodensis* Reed, since the trivial name *parri* is preoccupied by *G.*

(*Pseudogaudryina*) *parri* Cushman, 1936.

Occurrence.—AC-AF.

Genus **PSEUDOCLAVULINA** Cushman, 1936

Pseudoclavulina bradyana (Cushman)

Pl. 11, fig. 10

1936. *Listerella bradyana* Cushman, Cushman Lab. Foram. Res., Sp. Pub. 6, p. 40, pl. 6, fig. 11.

This species has been placed in the genus *Pseudoclavulina* as examination of a number of sections revealed no more than three chambers in the initial whorl, thus excluding this form from the genus *Schenckiaella* Thalmann, 1942 (= *Listerella* Cushman, 1933, preoccupied name). In his type description of *Listerella bradyana*, Cushman did not mention the initial chambers, nor are they shown in his type figure. In all other respects, the Heywood forms are identical with the type description.

Occurrence.—AD.

Pseudoclavulina rudis (Costa)

Pl. 11, figs. 3,6,12,14

1855. *Glandulina rudis* Costa, R. Accad. Sci. Napoli, Mem., vol. 2 (1855-57), p. 142, pl. 1, figs. 12, 13.

1937. *Liebusella rudis* (Costa), Cushman, Cushman Lab. Foram. Res., Sp. Pub. 8, pp. 168, 169, pl. 20, figs. 17-21.

Cushman placed this species in the genus *Liebusella*. Costa's original figures, however, do not show the labyrinthic chamber interior which is supposedly characteristic of this genus, and Cushman did not mention this feature in his description of the species (1937a, p. 168), nor is it well shown in his illustrations (1937a, pl. 20, figs. 20, 21). In a generic description subsequent to the original, Cushman (1937a, p. 163) stated "... the interior of the chambers often becomes distinctly labyrinthic ...". If this is not a constant feature, therefore, it is unreasonable to regard it as a generic criterion. Similarly, the aperture is recorded as "... often becoming complex or irregularly radiate in the adult ..."; once again, an unacceptable generic criterion because of its inconstancy. A taxonomic restudy of this and related genera, similar to Bowen's (1955) study of *Gaudryina* and its synonyms, is needed to show the exact nature of these structural differences among the arenaceous Foraminifera, and whether they have any value as generic or specific criteria.

Although a number of basal sections were made, no specimen was found to have more than three chambers in the initial whorl, which thus excludes this form from the genus *Schenckiaella* Thalmann, 1942, and the

aperture is always simple, sometimes with a short neck, but never with a tooth, thus excluding it from the genus *Martinottiella* Cushman, 1933. The present form is, therefore, placed in the genus *Pseudoclavulina* Cushman, 1936.

Occurrence.—AE-AG.

Genus **CLAVULINOIDES** Cushman, 1936

Clavulinoides victoriensis (Cushman)

Pl. 11, figs. 2, 9

1936. *Clavulinoides szabo* (Hantken) var. *victoriensis* Cushman, Cushman Lab. Foram. Res., Sp. Pub. 6, p. 22, pl. 3, figs. 19, 22.

This species shows variability in a number of features. In some specimens, the aperture is a simple terminal opening at the end of the last chamber, and in others, it is located at the end of a short cylindrical neck. In a few specimens, the sides are somewhat concave, whereas most have flat or slightly convex sides. The surface texture is also variable but mostly coarse and rough.

Occurrence.—AE, AF.

Family **MILIOLIDAE**

Genus **TRILOCULINA** d'Orbigny, 1826

Triloculina brochita Carter

1964. *Triloculina brochita* Carter, Geol. Surv. Victoria, Mem. 23, p. 59, pl. 1, figs. 3, 4.

This species shows much variation in amount of inflation of the chambers and of embracing of earlier chambers by the later ones.

Occurrence.—AC-AG.

Triloculina trigonula (Lamarck)

1804. *Miliolites trigonula* Lamarck, Mus. National Hist. Nat., Ann., vol. 5, p. 351; vol. 9 (1807), pl. 17, figs. 4a-c.

1826. *Triloculina trigonula* (Lamarck), d'Orbigny, Ann. Sci. Nat., sér. 1, vol. 7, p. 299, pl. 16, figs. 5-9.

Typical specimens occur throughout most of the Heywood marl. However, two specimens from core AE were identical with the typical form in all respects, except for a platelike tooth in the aperture, which distinguishes the genus *Triloculinella* Riccio, 1950. Because of the otherwise close similarity with typical *Triloculina* and the association of the two forms together in the same sample, some doubt is cast on the tooth as a constant morphological feature in *Triloculina*.

Occurrence.—AC-AG.

Genus **PYRGO** Defrance, 1824**Pyrgo bulloides** (d'Orbigny)

1826. *Biloculina bulloides* d'Orbigny, Ann Sci. Nat., sér. 1, vol. 7, p. 297, pl. 16, figs. 1-4.

The few specimens from cores AC, AF, and AG vary in the degree to which the last chamber envelopes the penultimate chamber. In some specimens the last chamber folds around most of the penultimate, so that in side view it has a distinct C-shape.

Occurrence.—AC, AF, AG.

Pyrgo inornata (d'Orbigny)

1846. *Biloculina inornata* d'Orbigny, Foraminifères fossiles du bassin tertiaire de Vienne (Autriche), p. 266, pl. 16, figs. 7-9.

There is some variation in the degree to which the last chamber embraces the penultimate, and in the position of the bifid tooth, which lies normally within the aperture, but in some specimens, projects beyond the apertural margin.

Occurrence.—AC, AD, AE, AG.

Genus **SIGMOILOPSIS** Finlay, 1947**Sigmoilopsis compressa** Hornibrook

1958. *Sigmoilopsis compressa* Hornibrook, New Zealand Jour. Geol. Geophys., vol. 1, No. 4, pp. 657, 671, figs. 5, 6, 11.

Specimens with a test composed of coarser sand grains than in the type species, but otherwise similar, are referred to this species. The size of the arenaceous material is considered to be an environmentally imposed, rather than a genetic, feature.

Occurrence.—AC-AE.

Genus **SPIROLOCULINA** d'Orbigny, 1826**Spiroloculina tenuiseptata** Brady

1884. *Spiroloculina tenuiseptata* Brady, Rep. Challenger Exped., Zool., pt. 22, vol. 9, p. 153, pl. 10, figs. 5, 6.

Carter (1958b, p. 30, pl. 2, figs. 1, 2) described and figured a similar form from near Birregurra, Victoria, as *S. canaliculata* d'Orbigny. His identification was based on a comparison with a topotype from Baden in the Vienna Basin. However, Cushman and Todd (1944, pp. 47, 48) recorded a specimen from Birregurra as *S. tenuiseptata*, pointing out that this species closely resembles *S. canaliculata*, but differs in having the inner part of each chamber depressed and the outer part strongly raised, while *S. canaliculata*

has both inner and outer margins raised. *S. tenuiseptata* is also apparently restricted to the Indo-Pacific region, whereas the other species has been recorded only from Europe and northern Africa.

Family **LAGENIDAE**

Genus **LAGENONODOSARIA** Silvestri, 1900

Lagenonodosaria scalaris (Batsch)

1791. *Nautilus (Orthoceras) scalaris* Batsch, Testaceorum arenulae marinae tabulae sex . . . (Sechs Kupfertafeln mit Conchylien des Seesandes), Jena, pp. 1, 4, pl. 2, figs. 4a, b.

Stainforth (1952, p. 14) restricted the name *Nodosaria* to species with radiate apertures and used the genus *Lagenonodosaria* for forms having a simple aperture at the end of a long thin tube ornamented by multiple rings or collars, and consisting of a small number of evenly arranged, globose, and usually striate or hispid chambers. The specimens of *L. scalaris* have from one to three, rarely four, chambers with variable longitudinal ornament as described by Heron-Allen and Earland (1924, p. 153) for forms from the "Filter Quarry", Moorabool River, Victoria.

Occurrence.—AA, AB, AF.

Family **POLYMORPHINIDAE**

Genus **GUTTULINA** d'Orbigny, 1839

Guttulina problema (d'Orbigny)

1826. *Polymorphina (Guttulina) problema* d'Orbigny, Ann. Sci. Nat., sér. 1, vol. 7, p. 266, No. 14.

Some specimens, ornamented with faint longitudinal costae, would be classified as *G. regina* by Brady, Parker, and Jones (1870), who stated (p. 241) that this latter species "may be regarded morphologically as *P. problema* with an ornamentation of longitudinal ribs." Here the ornamentation is regarded as an ecologic, rather than a specific, character, on the basis of observations on living Foraminifera by Heron-Allen (1915, p. 262).

Occurrence.—AD, AG, AH.

Guttulina spicaeformis (Roemer)

1838. *Polymorphina (Guttulina) spicaeformis* Roemer, Neues Jahrb. Min. Geogn. Geol. Petref.-Kunde, p. 386, pl. 3, figs. 31a, b.

Some forms with faint longitudinal costae are included also under this species for the same reasons given above under *G. problema*, in which a similar situation arises.

Occurrence.—AB, AG, AH.

Genus **SIGMOIDELLA** Cushman and Ozawa, 1928**Sigmoidella kagaensis** Cushman and Ozawa

Pl. 12, fig. 1

1928. *Sigmoidella kagaensis* Cushman and Ozawa, Cushman Lab. Foram. Res., Contr., vol. 4, p. 19, pl. 2, fig. 14.

Typical forms similar to that illustrated in Cushman and Ozawa (1930, pl. 39, fig. 5), as well as forms transitional between this species and *S. elegantissima*, were found in core AB. It is possible that only one species is represented. Transverse sections across the two species show that *S. kagaensis* (Pl. 12, fig. 1) has a much larger initial chamber than *S. elegantissima* (Pl. 12, fig. 6), and it may be that the forms typical of *S. kagaensis* are actually a different stage in the life cycle of *S. elegantissima*. However, no specimens of *S. kagaensis* were found associated with *S. elegantissima* in cores AE and AF. Further work is needed to resolve the question.

Occurrence.—AB.

Family **BULIMINIDAE**Genus **UVIGERINA** d'Orbigny, 1826**Uvigerina proboscidea** Schwager

1866. *Uvigerina proboscidea* Schwager, Novara Exped. 1857-1859, Geol. Theil, vol. 2, pt. 2, p. 250, pl. 7, fig. 96.

Besides the typical form, there are also specimens which, except for the lack of an acicular basal spine, are similar to the variety *vadescens* of Cushman (1933).

Occurrence.—AD, AH.

Genus **BOLIVINA** d'Orbigny, 1839**Bolivina victoriana** Cushman

1936. *Bolivina victoriana* Cushman, Cushman Lab. Foram. Res., Sp. Pub. 6, p. 52, pl. 7, figs. 16a, b.

There is considerable variation in the specimens examined. Some have the typical *Loxostomum* development whereas others are typical *Bolivina*. Hofker (1951, p. 47) and Bhatia (1956) showed that *Loxostomum* has no generic standing but is merely a developmental end-stage in *Bolivina*, and thus, no distinction is made between these variants in the samples studied. Some forms show faint longitudinal costae in the initial part of the test, but apart from this ornamentation, these cannot be distinguished from the typical form. It is probable that the specimens re-

corded and figured as *Loxostoma bentyanum* (Chapman) by Cushman (1937b, p. 180, pl. 21, figs. 6-8) belong to this species. Chapman's original *Bolivina bentjana* has since been shown to be an echinoid spine (Jenkins, 1958).

Occurrence.—AA-AD.

Family CHILOSTOMELLIDAE

Genus **PULLENIA** Parker and Jones, 1862

Pullenia bulloides (d'Orbigny)

1846. *Nonionina bulloides* d'Orbigny, Foraminifères fossiles du bassin tertiaire de Vienne (Autriche), p. 107, pl. 5, figs. 9, 10.

The specimens from the Heywood Bore and the type specimen of *P. bulloides* have four to four and a half chambers in the last whorl, compared with six chambers in the type specimens of *P. miocenica* Kleinpell. A specimen from the Miocene of eastern Victoria, intermediate between the two but referred to *P. miocenica* by Carter (1964, p. 71, pl. 2, figs. 46, 47), has five to five and a half chambers in the last whorl. In other respects, all are identical, and consequently must either belong to the same species, or be closely related.

Occurrence.—AA, AE-AH.

Family DISCORBIDAE

Genus **ROSALINA** d'Orbigny, 1826

Rosalina bertheloti d'Orbigny

1839. *Rosalina bertheloti* d'Orbigny, Foraminifères des Iles Canaries, in Barker-Webb and Berthelot, Hist. Nat. des Iles Canaries, vol. 2, pt. 2, Zool., p. 135, pl. 1, figs. 28-30.

This species is probably the same as that from the Aire coast near Cape Otway referred to *R. scopos* (Finlay) by Carter (1958b, pp. 41, 42, pl. 4, figs. 34-36).

Occurrence.—AA-AD, AF, AG.

Genus **GYROIDINOIDES** Brotzen, 1942

Gyroidinoides allani (Finlay)

1939. *Gyroidina allani* Finlay, Roy. Soc. New Zealand, Trans. Proc., vol. 69, pt. 3, p. 323, pl. 28, figs. 134-136.

The specimens found are somewhat smaller (0.83 mm) than the type species (1.3 mm.) but are otherwise typical. *G. zelandicus* (Finlay), also found in the Heywood section, is smaller than *G. allani*, and has eight to

nine chambers in the last whorl, compared with ten to eleven in *G. allani*.
Occurrence.—AE.

Genus **EPONIDES** Montfort, 1808

Eponides repandus (Fichtel and Moll)

1798. *Nautilus repandus* Fichtel and Moll, *Testacea microscopica aliaque minuta ex generibus Argonauta et Nautilus ad naturam delineata et descripta*, Vienna, (1803 reprint), p. 35, pl. 3, figs. a-d.

1958. *Eponides repandus* (Fichtel and Moll), Carter, *Geol. Sur. Victoria*, Bull. 55, pp. 45, 46, pl. 6, figs. 51-53.

This form shows great variability in the number of chambers in the last whorl, in the degree of convexity of both sides, in the development of accessory openings in the face of the last chamber, and in the limbidity of the dorsal sutures. Resig (1962) described the great variability in growth stages of *E. repandus* from the Californian Pleistocene, and her conclusions are supported by this study.

Forms comparable to those named *E. lornensis* by Finlay (1939, pp. 521, 522) occur together with those more typical of *E. repandus*, but all gradations between the two forms are present. They are thus grouped here under the same name.

Occurrence.—AB-AH.

Genus **MISSISSIPPINA** Howe, 1930

Mississippina concentrica (Parker and Jones)

1864. *Pulvinulina concentrica* Parker and Jones, *in* Brady, *Linn. Soc. London*, Trans., vol. 24, pt. 3, p. 470, pl. 48, figs. 14a, b.

1958. *Stomatorbina concentrica* (Parker and Jones), Carter, *Geol. Sur. Victoria*, Bull. 55, pp. 40, 41, pl. 4, figs. 37-39; pl. 7, fig. 75.

The present status of the genera *Mississippina* and *Stomatorbina* was discussed by Hornibrook (1961, pp. 114-115), and his conclusion that *Stomatorbina* is a synonym of *Mississippina* has been followed.

Occurrence.—AB-AH.

Genus **CANCERIS** Montfort, 1808

Canceris intermedius Cushman and Todd

1942. *Canceris intermedius* Cushman and Todd, *Cushman Lab. Foram. Res., Contr.*, vol. 18, p. 88, pl. 22, figs. 11, 12.

As Carter (1964, p. 85) observed, this species occurs with forms named *C. ovatus* by Cushman and Todd (1942, p. 89), as well as with transitional specimens. All are regarded as a single species.

Occurrence.—AA, AC, AD.

Genus **CIBICIDES** Montfort, 1808**Cibicides lobatulus** (Walker and Jacob)

1798. *Nautilus lobatulus* Walker and Jacob, in Kanmacher, F., Adams' Essays on the microscope. Ed. 2, p. 642, pl. 14, fig. 36.

The highly variable nature of the tests of this species has been discussed by a number of authors (Bhatia, 1956; Carter, 1951; Drooger, 1953; Dupeuble, 1962). Studies of the living animal by Nyholm (1961a, b) have revealed a complex life cycle, which not only confirms the conclusions of others regarding test variability, but also suggests that the variation may be even more extreme than previously thought.

Nyholm (1961a) concluded that the supposed genera *Cibicidella*, *Dyocibicides*, and *Stichocibicides* were all based on individual variation within the plastic species, *Cibicides lobatulus*. Although *Vagocibicides* was not mentioned by Nyholm, it also appears to be based on a variant of *Cibicides lobatulus* and, therefore, is another synonym of *Cibicides*. All these aberrant forms which were found in the Heywood samples with typical *Cibicides lobatulus*, have an initial *Cibicides*-like test before adopting their various erratic growth patterns.

Occurrence.—AA-AH.

Cibicides pseudoungerianus (Cushman)

1922. *Truncatulina pseudoungeriana* Cushman, U. S. Geol. Sur., Prof. Paper 129-E, p. 97, pl. 20, fig. 9.

Specimens from the Heywood Bore have been compared with the holotype and paratypes in the Cushman Collection in the National Museum, Washington, D. C., and are considered identical. This species is variable in the degree of convexity of both sides, and in the amount of clear shell material which obscures the early whorls of the test. It is probable that the form referred to *C. perforatus* by Carter (1958b, p. 46, pl. 6, figs. 57-59) belongs to this species also.

Occurrence.—AA-AC, AE-AI(1).

Cibicides mediocris Finlay

1940. *Cibicides mediocris* Finlay, Roy. Soc. New Zealand, Trans. Proc., vol. 69, pt. 1, p. 464, pl. 67, figs. 198, 199.

This species appears to be fairly constant in its characters, varying only in the amount of inflation of the last-formed chambers.

Occurrence.—AA, AB, AD-AF.

Cibicides victoriensis Chapman, Parr, and Collins Pl. 15, figs. 13-15

1934. *Cibicides victoriensis* Chapman, Parr, and Collins, Linn. Soc. London, Jour., Zool., vol. 38, p. 571, pl. 9, figs. 16a-c.

The spiral surface of the test of this distinctive species, whose initial appearance indicates Faunal Unit 11 (Carter, 1964, p. 43) or the Bairnsdalian Stage of the Victorian Tertiary, is covered by a variable amount of secondary shell material. In some specimens, this obscures the sutures of all chambers save those of the last-formed whorl, while other specimens have only a small accumulation on the earliest one or two whorls.

Occurrence.—AA.

Family **PLANORBULINIDAE**Genus **CARPENTERIA** Gray, 1858**Carpenteria rotaliformis** Chapman and Crespín Pl. 12, figs. 4,7,8,11

1930. *Carpenteria rotaliformis* Chapman and Crespín, Roy. Soc. Victoria, Proc., n.s., vol. 43, pp. 98, 99, pl. 5, figs. 7, 8.

A good description of the development and mode of growth of this species, in agreement with observations made on the Heywood specimens, was published by Glaessner and Wade (1959, p. 200).

Occurrence.—AB, AD-AF.

Family **CAMERINIDAE**Genus **CAMERINA** Bruguière, 1792**Camerina complanata** (Defrance) Pl. 12, figs. 2,5,9,10,12

1882. *Lenticulites complanata* Defrance, Dict. Sci. Nat., vol. 25, p. 453.

1938. *Operculina victoriensis* Chapman and Parr, Roy. Soc. Victoria, Proc., n.s., vol. 50, pp. 284-287, pl. 16, figs. 3-8, text fig. 1.

The internal structure of specimens from the Heywood Bore (Pl. 12, figs. 5, 10, 12) is the same as that of Recent and fossil specimens identified as *C. complanata* by Cole (1959, pl. 29, fig. 16; pl. 31, figs. 2-4; 1961, pl. 15, fig. 1; pl. 16, figs. 1-9), and it compares well with the structure of "*Operculina victoriensis*" as shown in the type figures of Chapman and Parr (1938, pl. 16, figs. 4, 5, 8).

The Heywood specimens of *Camerina complanata* exhibit the same variations in ornament as that described for "*Operculina victoriensis*" by Chapman and Parr (1938, pp. 284-287) and Carter (1964, pp. 128, 129). Topotype specimens of *Camerina complanata* from Dax, France, in the Cushman Collection at the U. S. National Museum, Washington, D. C.,

show a similar variation in ornament. The test may be entirely smooth, or may be beaded, and have raised, often beaded, limbate sutures (Pl. 12, figs. 2, 9). Intermediate combinations of beading and sutural ornament occur. The test ornament is unrelated to internal characters such as proloculus size, or number of chambers per whorl, and is apparently an ecologically controlled feature. An ecologic, rather than a genetic control was suggested previously for the variable ornament in "*Operculina*" *floridensis* (Cole, 1958, p. 193) and in *Camerina complanata* (Cole, 1961, p. 122).

Occurrence.—AA, AB.

C. PLANKTONIC SPECIES

Family **GLOBIGERINIDAE**

Genus **GLOBIGERINA** d'Orbigny, 1826

Globigerina angustiumbilitata (Bolli) Pl. 13, figs. 1-6; Pl. 14, fig. 2
1957. *Globigerina ciperoensis angustiumbilitata* Bolli, U. S. Nat. Mus., Bull. 215, p. 109, pl. 22, figs. 12a-c, 13a-c.

The final chamber in this species is subject to variation in shape and size, ranging from the normal spherical chamber down to what may be regarded as a large apertural lip on the penultimate chamber. No taxonomic significance is attached to the aberrant final chamber. Takayanagi and Saito (1962, p. 74) have given good reasons why they do not consider this feature to be the basis for specific distinction in this or in other planktonic species in which it also occurs.

Occurrence.—Common in cores AF-AH, rarer in AA, AC, AE.

Globigerina ciperoensis Bolli Pl. 14, figs. 6-8
1954. *Globigerina ciperoensis* Bolli, Cushman Found. Foram. Res., Contr., vol. 5, pt. 1, pp. 1, 2 textfigs. 3, 3a, 4, 4a-b, 5, 5a-b, 6.
1957. *Globigerina ciperoensis ciperoensis* Bolli, U. S. Nat. Mus., Bull. 215, p. 109, pl. 22, figs. 10a-b.

G. ciperoensis "*angulisuturalis*" has not been recognized in the Heywood material, although it occurs with the typical form in the Lakes Entrance samples (Jenkins, 1960, p. 350) and in samples from the Caribbean region (Bermudez, 1960, p. 1166).

Occurrence.—Scarce in cores AF and AG.

Globigerina euapertura Jenkins Pl. 13, figs. 7, 14, 15
1960. *Globigerina euapertura* Jenkins, Micropaleont., vol. 6, p. 351, pl. 1, figs. 8a-c.

This species extends higher in the Heywood Bore than in the Lakes

Entrance Oil Shaft, from where it was originally described. As pointed out by Jenkins (1960, p. 351), the height of the aperture varies within any population of *G. euapertura*, and this is confirmed by the Heywood specimens.

Occurrence.—Frequent in cores AG and AH, scarcer in AF; rare in AI(1)?

Globigerina falconensis Blow

Pl. 13, figs. 8-10

1959. *Globigerina falconensis* Blow, Bull. Amer. Paleont., vol. 39, No. 178, p. 177, pl. 9, figs. 40a-c, 41.

Specimens from the Heywood Bore have been compared with the holotype and paratypes in the U. S. National Museum Collection at Washington, D. C., and are considered identical.

Occurrence.—Frequent in cores AA and AB.

Globigerina glutinata Egger

Pl. 13, figs. 16, 23, 24

1893. *Globigerina glutinata* Egger, K. bayer. Akad. Wiss., math.-physik. Cl., Abh., vol. 18, pt. 2 (1893), p. 371, pl. 13, figs. 19-21.

1962. *Globigerina glutinata* Egger, Takayanagi and Saito, Sci. Rep. Tohoku Univ., ser. 2 (geol.), Sp. vol. 5, pp. 86-88, pl. 27, figs. 13a-c, 17a-c.

An accessory aperture occurs in some specimens, especially in core AD. A good discussion of the significance of this feature was published by Takayanagi and Saito (1962, p. 87), who regarded it as of no taxonomic importance.

Occurrence.—Frequent in cores AA-AC, scarcer in AD.

Globigerina praebulloides Blow

Pl. 13, figs. 25-27

1959. *Globigerina praebulloides* Blow, Bull. Amer. Paleont., vol. 39, No. 178, pp. 180, 181, pl. 8, figs. 47a-c; pl. 9, fig. 48.

Specimens from the Heywood cores have been compared with the holotype and paratypes in the U. S. National Museum Collection in Washington, D. C., with which there is good agreement.

Some specimens, particularly in cores AF-AH, but also in the other cores from the upper part of the Gambier limestone, possess a bulla covering the umbilicus. It is usually in the form of a flattened plate but occasionally may be inflated. Jenkins (1960, p. 356) recorded similar forms from the Lakes Entrance Oil Shaft as *Catapsydrax* cf. *stainforthi* Bolli, Loeblich and Tappan. Here, however, the opinion of Hofker (1959; 1961) that the bulla possesses no taxonomic value but is merely a feature developed during reproduction, is followed in placing these bullate

forms in the genus *Globigerina*. On removal of the bulla, no difference can be seen from normal *G. praebulloides*.

Occurrence.—Abundant in cores AA-AH, rare in AI(1).

***Globigerina trilocularis* d'Orbigny**

Pl. 13, figs. 17-19

1826. *Globigerina trilocularis* d'Orbigny, Ann. Sci. Nat., sér. 1, vol. 7, p. 277, no. 2 (nom. nud.).

1832. *Globigerina trilocularis* d'Orbigny, Deshayes, Encyclopédie Méthodique; Histoire naturelle des vers, vol. 2, pt. 2, p. 170.

1897. *Globigerina trilocularis* d'Orbigny, Fornasini, Rend. R. Accad. Sci. Ist. Bologna, n.s., vol. 2 (1897-1898), fasc. 1, pl. 1, figs. 6, 7, 7a; p. 12, textfig.

1962. *Globigerina trilocularis* d'Orbigny, Takayanagi and Saito, Sci. Rep. Tohoku Univ., ser. 2 (Geol.), Sp. vol. 5, p. 91, pl. 25, figs. 5a-c.

Jenkins (1960, p. 352) recorded from the bottom part of the Lakes Entrance Oil Shaft "... a variety of *Globigerina praebulloides* Blow, which tends to have only three chambers in the final whorl...". His description of this indicates that it is probably the same as the present species, which possesses a low arched to slitlike aperture and a relatively smooth test.

Occurrence.—Common in cores AF-AG, rare in AE.

***Globigerina woodi* Jenkins**

Pl. 13, figs. 11-13

1960. *Globigerina woodi* Jenkins, Micropaleont., vol. 6, p. 352, pl. 2, figs. 2a-c.

This species is distinguished from the related forms, *G. falconensis*, *G. praebulloides*, and *G. trilocularis*, by its coarsely pitted surface. The position and size of the aperture varies within the species as described by Jenkins (1960, p. 352).

Occurrence.—Common to abundant in cores AA-AF.

Genus *GLOBIGERINOIDES* Cushman, 1927

***Globigerinoides bisphericus* Todd**

Pl. 15, figs. 1,2

1954. *Globigerinoides bispherica* Todd, in Todd, Cloud, Low and Schmidt, Amer. Jour. Sci., vol. 252, No. 11, p. 681, pl. 1, figs. 1a-c, 4.

The longer stratigraphic range of this species in the Heywood Bore and as recorded by Carter (1958a, b; 1958/59; 1964) from other Victorian occurrences compared with the shorter range ascribed to it in the Caribbean region (Bolli, 1957; Blow, 1959) and in eastern Victoria (Jenkins, 1960) has been discussed under the section on "Correlation with Caribbean planktonic zones." In the Caribbean region, Bermudez (1960, p. 1241) recorded a longer stratigraphic range than given by Bolli for this species. Moreover, Bermudez regarded *G. bisphericus* as synonymous with *G. sicanus* de Stefani.

Occurrence.—Scarce in cores AB and AD.

Globigerinoides glomerosus Blow

Pl. 15, figs. 5,6,8,9

1956. *Globigerinoides glomerosa* Blow, Micropaleont., vol. 2, p. 64, textfig. 1, Nos. 9-19; textfig. 2, Nos. 1-4.

Blow (1956) recognized three subspecies of this form, each with a supposedly slightly different stratigraphic range, making up a bioseries linking *G. bisphericus* Todd with *Orbulina suturalis* Brönnimann. However, as Bermudez (1960, p. 1229) pointed out, it is difficult in practice to separate the three forms. Because they are found together in the same sample, they cannot by definition be subspecies (Mayr, Linsley, and Usinger, 1953, p. 37; Boltovskoy, 1958, p. 199) but are best regarded as variations or forms.

Occurrence.—Frequent in core AA (all three "subspecies" recognized).

Globigerinoides ruber (d'Orbigny)

Pl. 14, figs. 14-16

1839. *Globigerina rubra* d'Orbigny, Foraminifères, in de la Sagra, Histoire physique et naturelle de l'Ile de Cuba, p. 82, pl. 4, figs. 12-14.

Occurrence.—Frequent in core AB.

Globigerinoides trilobus (Reuss)

Pl. 14, figs. 17-21

1850. *Globigerina triloba* Reuss, K. Akad. Wiss. Wien, Math.-Nat. Cl., Denkschr., vol. 1, p. 374, pl. 47, figs. 11a-e.

Bolli (1957, p. 112) described the relationships between members of the *G. trilobus* group. Because they may occur together in the same sample, however, the members of the group are not subspecies but are to be regarded rather as variations or forms. *G. trilobus* "*trilobus*" and *G. trilobus* "immaturus" were the only forms found in the Heywood samples.

Occurrence.—Common in cores AA-AD.

Genus **ORBULINA** d'Orbigny, 1839**Orbulina bilobata** (d'Orbigny)

Pl. 15, fig. 3

1846. *Globigerina bilobata* d'Orbigny, Foraminifères fossiles du bassin tertiaire de Vienne (Autriche), p. 164, pl. 9, figs. 11-14.1956. *Biorbulina bilobata* (d'Orbigny), Blow, Micropaleont., vol. 2, p. 69, textfig. 2, No. 16.

The taxonomic status of this species is at present unsettled. It always occurs in association with *O. universa*, and some authors (e.g., Jenkins, 1960, p. 356; Belford, 1962, p. 8), therefore, regard it simply as a growth form of this latter species. Other authors (e.g., Blow, 1956, p. 69; Bermudez, 1960, p. 1255) have given it generic status, having no direct relation with *Orbulina*. The former view seems more reasonable at present, but because of the doubt concerning the life history of *O. universa*, *O. bilo-*

bata has been retained as a separate species until further evidence is forthcoming.

Occurrence.—Scarce in core AA.

***Orbulina suturalis* Brönnimann**

Pl. 15, fig. 7

1951. *Orbulina suturalis* Brönnimann, (part), Cushman Found. Foram. Res., Contr., vol. 2, p. 135, textfig. 2, Nos. 1,2,5-8,10; textfig. 3, Nos. 3-8,11,13-16,18,20-22; textfig. 4, Nos. 2-4,7-12,15,16,19-22.

1956. *Orbulina suturalis* Brönnimann, Blow, Micropaleont., vol. 2, p. 66, textfig. 2, Nos. 5-7.

Some specimens are difficult to distinguish from *Globigerinoides glomerosus* "circularis", and it may be preferable to regard the latter as a synonym of *O. suturalis*, as has been done by Chang and Yen (1958, p. 51), who do not accept Blow's emendation of Brönnimann's original diagnosis.

Occurrence.—Abundant in core AA.

***Orbulina universa* d'Orbigny**

Pl. 15, fig. 4

1839. *Orbulina universa* d'Orbigny, Foraminifères, in de la Sagra, Histoire physique, politique et naturelle de l'île de Cuba, p. 2, pl. 1, fig. 1.

Hofker (1956b; 1959) suggested that this form may include several species, in that it probably represents a reproductive stage of several species of *Globigerina*. This is supported to some extent by the fact that different wall structures can be found in specimens from the same Recent populations (Hofker, 1956b, p. 236), and from the same fossil populations (Belford, 1962, p. 7), and would account for the wide distribution of *O. universa* in the present seas (Parker, 1960, p. 80).

A factor that may impede the solution of the problem of the identity of *O. universa* in the future is that the initial globigerine portion of the test is apparently resorbed during the course of the reproductive process as the animal slowly sinks from the surface down to a depth of around 300 m., so that only the final spherical chamber remains (Le Calvez, 1936, p. 128). Without the initial chambers of the test it may be difficult to establish the true nature of this form from anything but living material. No evidence has yet been found for dimorphism associated with alternation of sexual and asexual reproduction in *O. universa*. This may be because there is no such alternation, the form itself representing one type of reproduction with the other type occurring in the globigerine stage.

Until this question is resolved, one can do nothing but retain *O. universa* in its presently held state as a form-species, rather than as an established genetic species.

Occurrence.—Abundant in core AA.

Genus TURBOROTALIA Cushman and Bermudez, 1949

Hofker (1956a, p. 371) pointed out that a number of forms similar to "*Globorotalia*" *centralis*, the type species of *Turborotalia*, "do not show the characters of *Globorotalia*, but those of *Globigerina*, with a nearly closed umbilicus and a sutural aperture," and are "actually globigerines in which the test has become more or less compressed and the umbilicus more or less closed." Although it may ultimately prove to be a synonym of *Globigerina*, the genus *Turborotalia* is retained for these forms.

The suprageneric position of *Turborotalia* is unsettled. Bermudez (1960, p. 1315) placed *Turborotalia* with *Globoquadrina* in the family Globorotaliidae. He considered *Turborotalia* to be more closely related to *Globoquadrina* than to *Globigerina*, the only difference being that *Turborotalia* lacks the typically globoquadrine tooth or valvular plate at the base of the septal face of each chamber. Although he classified *Globoquadrina* as a globorotaliid, Bermudez (1960, p. 1307) stated that *Globoquadrina* and *Globigerina* probably intergrade, a statement seemingly contradictory to his classification. Parker (1962, p. 235) classified the two genera as globorotaliids on the basis of similarity in wall structure, but she noted that whereas most species of *Turborotalia* have a globorotaliid type of wall structure, some species may have a globigerinid wall structure, thus revealing a flaw in the basis of her classification. Bolli, Loeblich and Tappan (1957, p. 20) placed *Globoquadrina* in the family Globigerinidae but retained *Turborotalia* as a subgenus of *Globorotalia* in the family Globorotaliidae. The two genera however, are obviously too closely related to be placed in separate families. In this article, both are placed in the family Globigerinidae, following Hofker's (1956a) conclusions regarding the relationship of *Turborotalia* with *Globigerina*.

***Turborotalia extans* (Jenkins)**

Pl. 13, figs. 20-22

1960. *Globorotalia extans* Jenkins, Micropaleont., vol. 6, p. 360, pl. 4, figs. 4a-c, 5a-c.

Only the megalospheric form with four chambers (see Jenkins, 1960, p. 360) in the final whorl was found in the Heywood material.

Occurrence.—Scarce in cores AG and AH.

***Turborotalia increbescens* (Bandy)**

Pl. 14, figs. 11-13

1949. *Globigerina increbescens* Bandy, Bull. Amer. Paleont., vol. 32, No. 131, p. 120, pl. 23, figs. 3a-c.

The specimens obtained agree well with the type description and figures.

Occurrence.—Scarce to frequent in cores AG and AH, rare in AF.

?Turborotalia opima (Bolli)

Pl. 14, figs. 3-5

1957. *Globorotalia opima opima* Bolli, U. S. Nat. Mus., Bull. 215, pp. 117, 118, pl. 28, figs. 1a-c, 2.

A single specimen from core AG having five chambers in the last whorl, but with a somewhat reduced or aborted final chamber, has been referred to this species. If the final chamber is not considered, it compares reasonably well with Bolli's illustration of the holotype. However, because of its aborted form and the lack of additional specimens, its identification is in doubt, and for this reason it is not shown on the correlation chart. Bermudez (1960, p. 1322) considered this species a synonym of *T. increbescens* (Bandy).

Occurrence.—One specimen in core AG.

Genus **GLOBOQUADRINA** Finlay, 1947

Globoquadrina dehiscens (Chapman, Parr and Collins) Pl. 15, figs. 10-12

1934. *Globorotalia dehiscens* Chapman, Parr and Collins, Linn. Soc. London, Jour., Zool., vol. 38, p. 569, pl. 11, figs. 36a-c.

The probable reason for the extreme scarcity of this species below core AB in the Heywood marl has been already discussed in the section on "Influence of oceanic circulation on planktonic fauna."

Occurrence.—Abundant in core AB, frequent in AA, rare (one specimen) in AE.

Family **GLOBOROTALIIDAE**

Genus **GLOBOROTALIA** Cushman, 1927

Globorotalia menardii "praemenardii" (Cushman and Stainforth)

Pl. 14, figs. 1.9, 10

1945. *Globorotalia praemenardii* Cushman and Stainforth, Cushman Lab. Foram. Res., Sp. Pub. 14, p. 70, pl. 13, figs. 14a-c.

1959. *Globorotalia menardii praemenardii* (Cushman and Stainforth), Blow, Bull. Amer. Paleont., vol. 39, No. 178, p. 215, pl. 18, figs. 118a-c.

This variation is smaller and more equally biconvex than typical *G. menardii*, with which it intergrades in the uppermost part of the *Globorotalia fohsi barisanensis* Zone in Venezuela (Blow, 1959, p. 215). It is extremely rare in the Heywood section, one specimen only being obtained from core AA. The reason for its rarity has been suggested in the section on "Influence of oceanic circulation on planktonic fauna."

Occurrence.—Rare in core AA.

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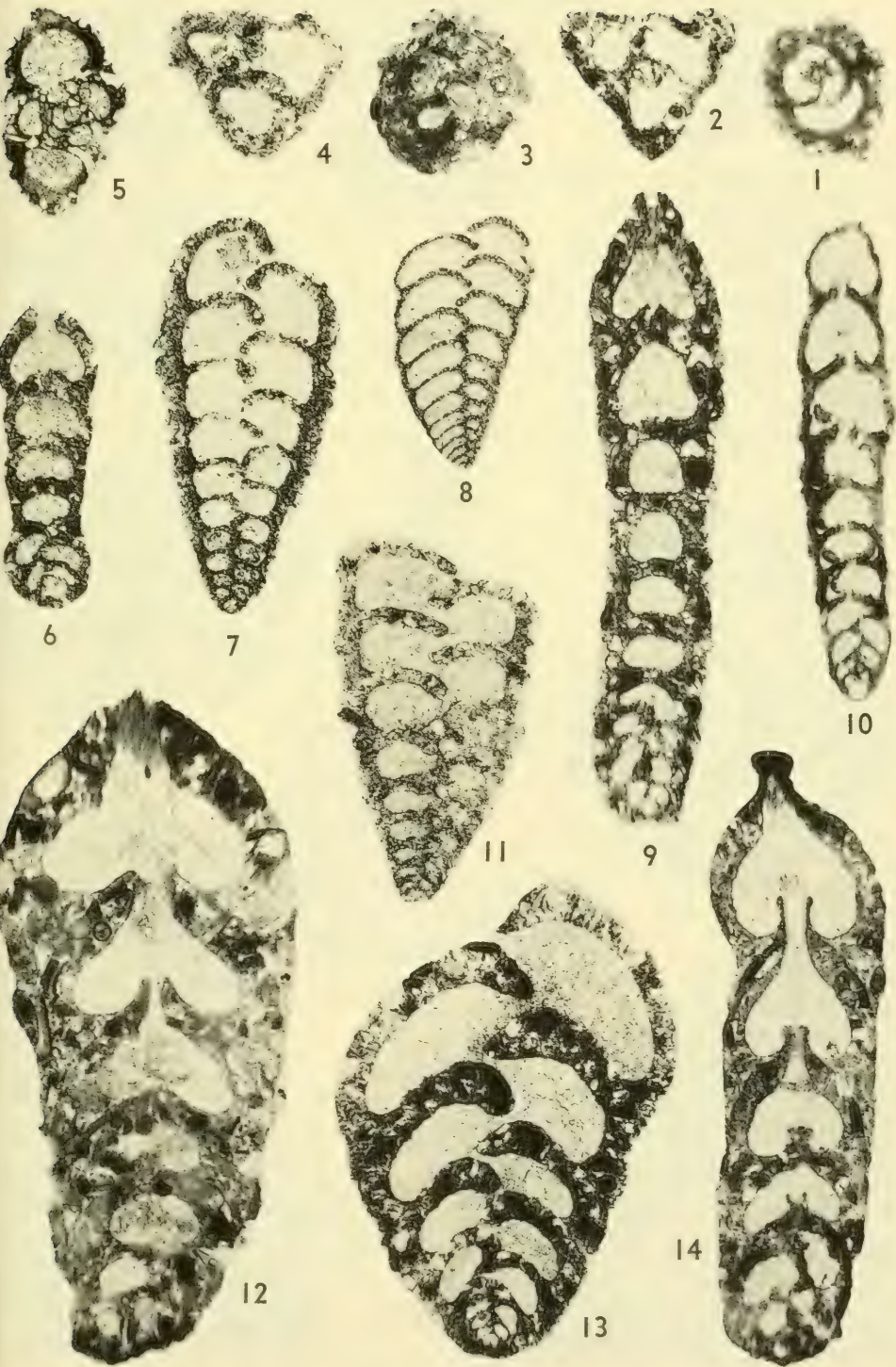
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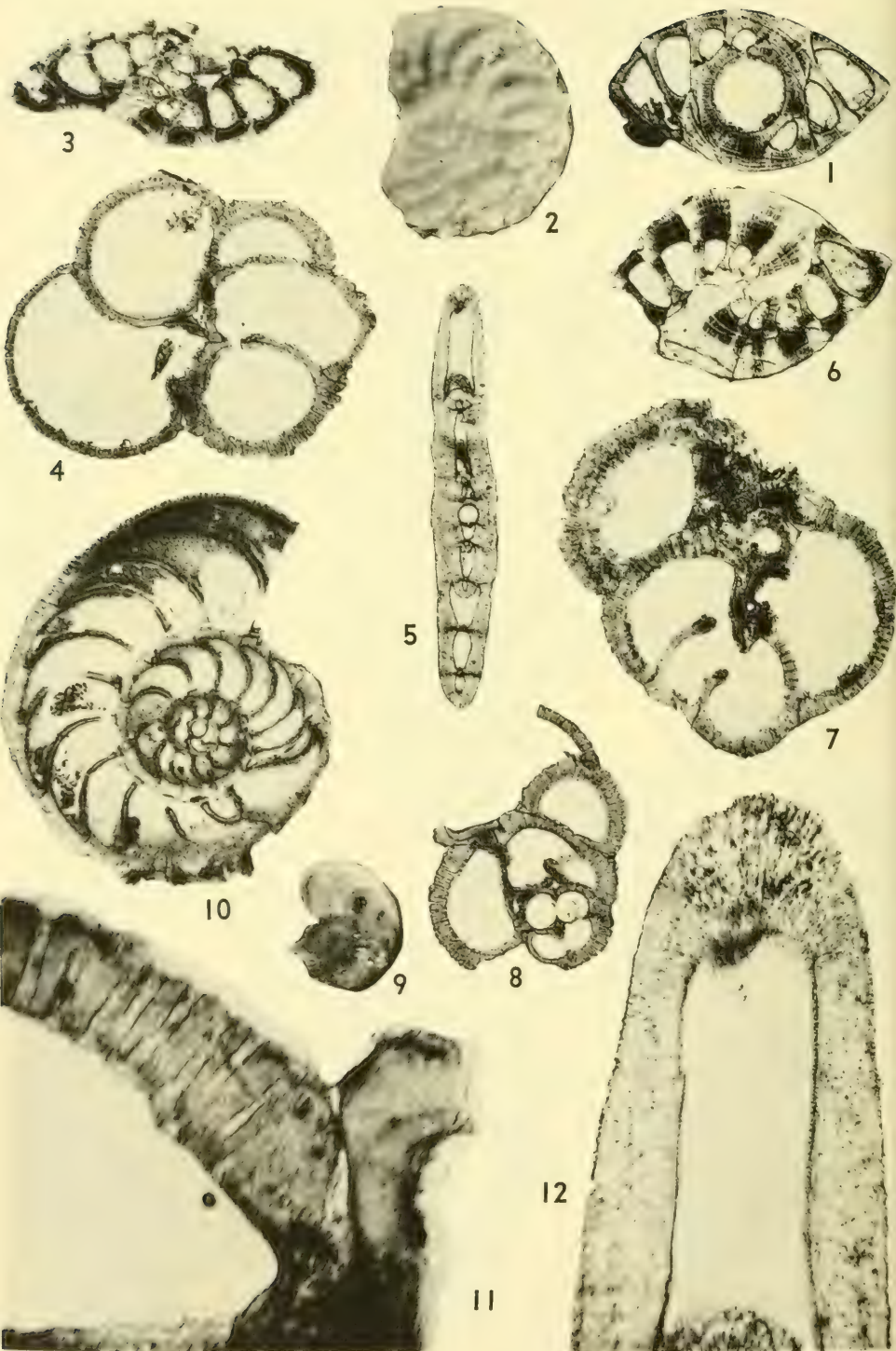
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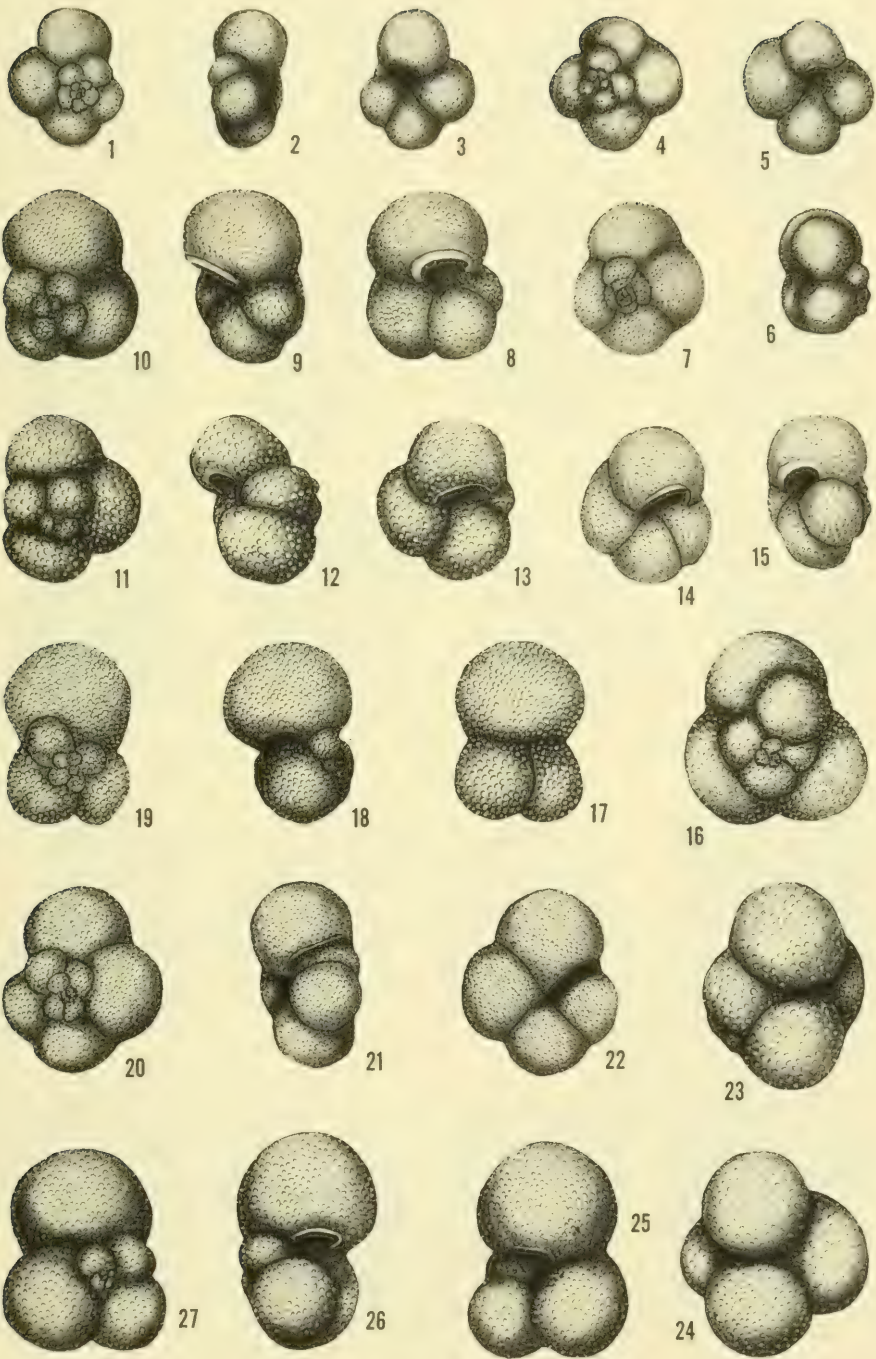
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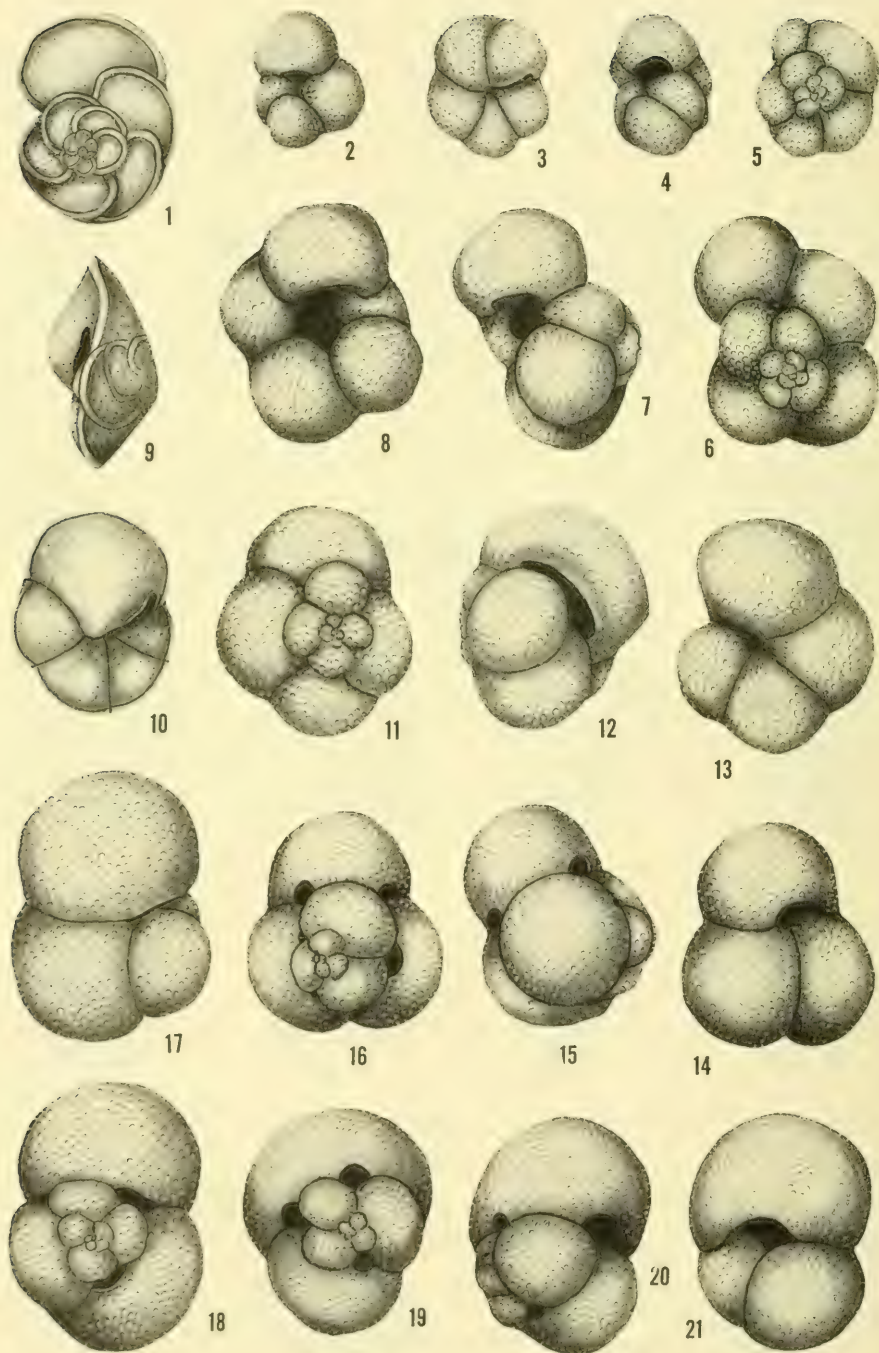
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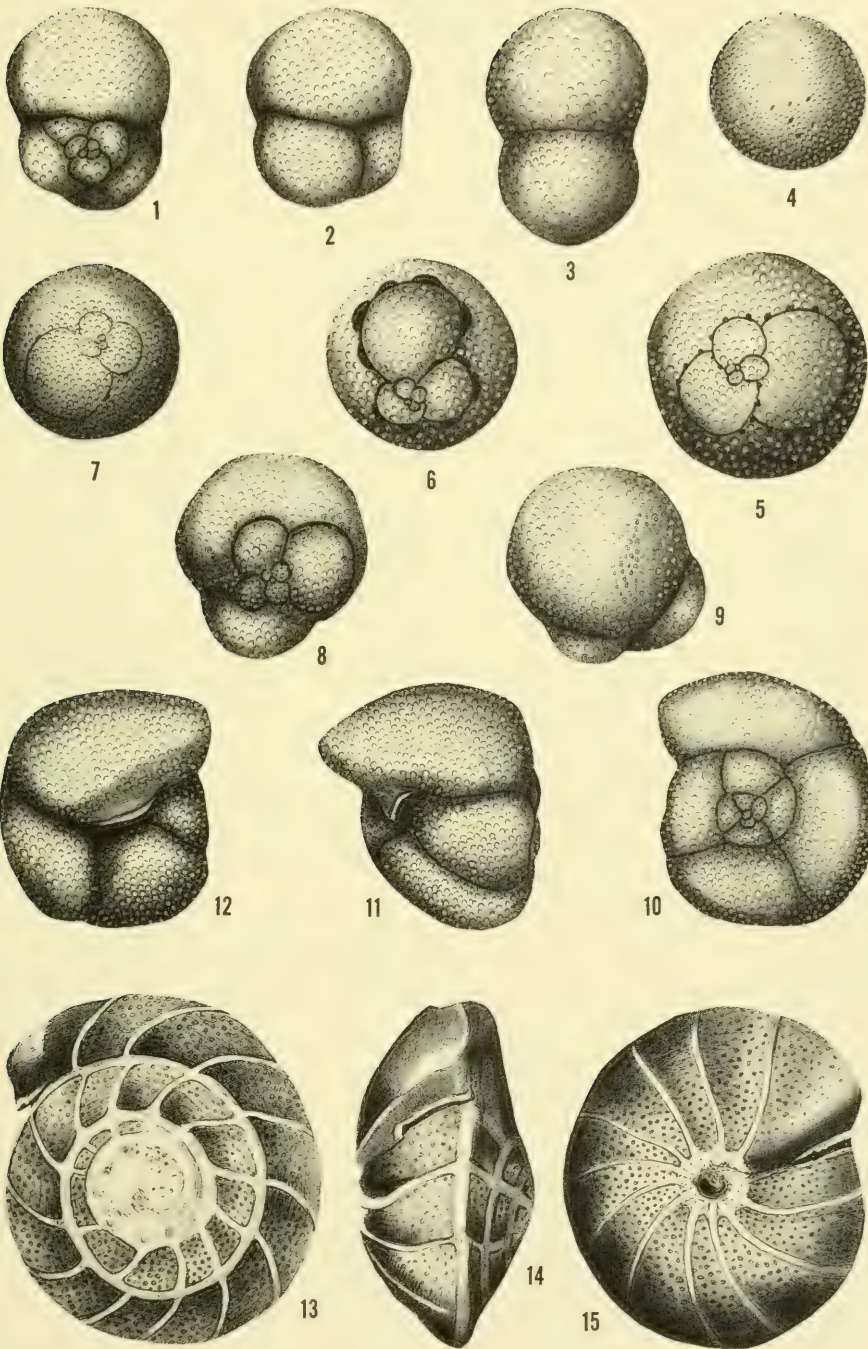
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**NORTH AMERICAN SOLUTA
(CARPOIDEA, ECHINODERMATA)**

By

RONALD L. PARSLEY

and

KENNETH E. CASTER

The University of Cincinnati

April 21, 1965

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NORTH AMERICAN SOLUTA
(CARPOIDEA, ECHINODERMATA)¹

RONALD L. PARSLEY

and

KENNETH E. CASTER

Department of Geology
The University of Cincinnati

ABSTRACT

Solute carpoids (Upper Cambrian-Lower Devonian) are represented in North America by two Ordovician genera and one problematic Upper Cambrian form from Nevada which is the oldest known member of the order.

Syringocrinus Billings, 1859 (Middle and Upper Trentonian of Ontario and Quebec) hitherto known only by part of its stele ("stem") is now seen from new material to have a bilaterally symmetrical, elevated theca with a single antero-dorsal arm, differentiated marginal and somatic plates, of which the dorsal plates retain the primitive dendrocystitid polyplate arrangement. The proximal stele is tetramerous and imbricates both antero-posteriorly and sagittally. The distal stele is composed of three azygous series of plates (left, dorsal and right) and is divided into two parts. The proximal portion (dendrostyloid) is uniquely rigid due to the continuous dorsal series and ankylosis in the right series; in the distal portion the dorsal series is discontinuous and the broad sutures bespeak flexibility. Along the left series of plates there are prominent plowshare-like sutural flanges and elevated nodes for anchoring or dragging in the substrate, in a manner analogous to the mirate styloid.

Iowacystis Thomas and Ladd, 1926, is also bilaterally symmetrical and is somewhat homeomorphic with the mirate *Dalejocystis* Prokop, 1963. Restudy shows a bivalved anal system and the marginals and upper somatic plates bear prominent prosopon which suggests that some sort of external "tissue" system was present.

These genera have undergone much independent development from the parent "dendrocystitid" stock and show remarkable convergence with the carpoid order Mitrata.

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The exceptional new material of *Syringocrinus* from the Middle Ordovician of Canada was collected by Dr. G. Winston Sinclair of the Canadian Geological Survey and generously made available to the authors for study. Dr. Sinclair also made available the type material in the Survey collections of *Syringocrinus paradoxicus* Billings. We are also indebted to Dr. T. E. Bolton for curating and cataloging the Sinclair material.

The type materials of *Iowacystis sagittaria* Thomas and Ladd were loaned for study by the Geology Department of the State University of Iowa. We are grateful to Dr. Robert Hansman for his efforts in this connection.

¹Read by title, Geol. Soc. America, New York, 1963.

Dr. Georges Ubaghs of the Université de Liège, Belgium, has shown valued interest in the project and generously made available a part of his then unpublished manuscript on some new Cambrian carroids from Nevada (Ubaghs, 1963). This material was loaned us for study by Dr. Porter M. Kier, curator of echinoderms in the United States National Museum.

Once again Cincinnati paleontologists are beholding to Mrs. Elizabeth K. Dalvé for her fine draughtsmanship. The text figures were drawn by Mrs. Dalvé and their excellence is manifest.

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INTRODUCTION

The carroid echinoderm order *Soluta* is represented in North America by only two Ordovician genera, *Iowacystis* Thomas and Ladd, 1926, and *Syringocrinus* Billings, 1859, and an unnamed Upper Cambrian stele described by Ubaghs (1963). The second of these was hitherto known in the literature from a single, poorly preserved proximal stele and part of the mesostele. New specimens of *Syringocrinus* here studied came from Trenton age limestones of Ontario and Quebec. For the first time thecal details are available for analysis. The holotype of Billings has also been restudied and reveals several new traits.

The four type specimens of *Iowacystis*, loaned by the State University of Iowa, constitute all the known material of this genus. They came from the Fort Atkinson limestone member, middle Maquoketa shale (Upper Ordovician: Richmond). Restudy of this material has likewise revealed new information.

The classification used in this work, devised by Gill and Caster, 1960, is as follows:

Phylum ECHINODERMATA Klein, 1734²

Class CARPOIDEA Jaekel, 1900; emend., 1921

Subclass HOMOIOSTELEA Gill and Caster, 1960

Superorder ASTYLOPHORA Gill and Caster, 1960

Order SOLUTA Jaekel, 1900

Family **IOWACYSTIDAE** Gill and Caster, 1960; emend.

Family **SYRINGOCRINIDAE**, nov.

The basis of this carpoid classification rests on the lateral and longitudinal differentiation of the stele and the nature of the theca. In summary, Carpoidea are differentiated from bilaterally symmetrical pelmatozoans (*e.g.*, eocrinoids, paracrinoids, and some cystoids) in that the stele is not a "stem" or "stalk" made up of columnals, but is generally composed of dimeres or tetrameres proximally (*i.e.*, two or four elements required to complete the circumference) and of variously plated distal steles (usually tending toward a dimerous arrangement).

The subclasses are based on whether the steles are longitudinally differentiated or maintain the same organization throughout their length. The former are the Homoiostealea; the latter the Homostealea, which will not be dealt with here.

Further subdivision of the subclass Homoiostealea is based on the presence or absence of a stylocone or styloid on the ventral (lower) proximal portion of the distal stele. This region is often called the median stele. Carpoids of this subclass with either of these structures are placed in the superorder Stylophora. Stylophora with stylocones constitute the order Cornuta. The stylocone structure is cone-shaped, hollow, and is a transitional section between

²The "subphylum" Pelmatozoa of conventional classifications is here deliberately omitted; not only were the Carpoidea not pelmatozoic (fixed in life), but there is no evidence that they are in any wise related to fixed forms, unless in an unknown Pre-Cambrian evolutionary grade. With the discovery of the Helicoplacoida of Durham and Caster (1963) from the *Olenellus* zone, additional impetus is given to the need for complete re-examination of the philosophy of echinodermal evolution. The helicoplacoids and some Eocrinoidea (Lower Cambrian in age) were, as Caster and Pope (1960) have indicated, vagile benthos, probably as free as are the holothurians. To our minds there are no communities of traits among echinoderms which justify the traditional cleavage of the phylum into "Pelmatozoa" and "Eleutherozoa." At best these terms can serve a useful function in their adjectival form as expressions of recurrent habitues among echinoderms.

proximal and distal steles proper. The Cornuta have "flat", *i.e.* depressed, usually small, irregularly and polygonally plated thecae. In most cases they have a well-defined set of marginal plates with a longitudinal or diagonal brace extending across the ventral surface. (*e.g.*, *Cothurnocystis*, *Phyllocystis*). Those with a styloid typify the order Mitrata. The styloid is a highly variable structure possessing blades, teeth or analogous (perhaps homologous) projections inserted along the ventral midline or composed of a series of segments with ventral projections.³

The styloid was solid, not possessing a lumen as did the stylocone, and seems to have functioned both as a temporary anchor and locomotor organ (Caster, 1952), whereas the stylocone was apparently more of a supporting and articulating structure. Mitrata thecae are usually nearly bilaterally symmetrical (*i.e.*, except for the "anomalocystid" plate of the inferior surface), ventrally slightly concave, somewhat vaulted dorsally, and bearing usually at each distal (anterior?) corner a rodlike process which articulated by a ball in a thecal socket. The processes curve somewhat toward the midline of the animal. A single processes is also characteristic of some mitrata taxa.⁴

With the possible exception of *Dendrocystoides scotica*, non-American solutes have a median stele zone consisting of several multi-plated segments which serve as a transitional area between the more massive proximal stele and attenuated distal stele. *Iowacystis* has little median stele and the distal portion simply emerges, taperingly, from the proximal. In *Syringocrinus* the median stele is expressed as the dendrostyloid, an unsymmetrical structure with a continuous series of dorsally intercalated plates which give the stele added rigidity. Isolated, intercalated plates are

³Ubaghs, 1961, has proposed a reversed orientation for the Cornuta and the Mitrata. He postulates that the "stele" of these orders is an endoskeletal support of a tentacle-like extension of the hydrocoel and that its primary role is subvective. He argues that there is an ambulacral groove running the length of the aulocophore ("stele"), and that the anus is located at the distal end of the theca. This is somewhat the same idea put forth by Chauvel, 1941 (pp. 229-233) for some of the Mitrata where he found what were thought to be "ganglia" in the proximal corners of the theca. He also placed the mouth in the proximal position with the anus opening into a distal thecal cloaca.

⁴See Caster (1952, p. 10) for discussion on habitus vs. phylogenetic orientation.

seen on the dorsal portion of the distal stele also. These isolated plates are quadrangular and generally are surrounded by four plates, two from each side. Such intercalations, exclusive of the true median stele, are unknown in non-American Soluta. In *Iowacystis* isolated plates between one or two sets of dimeres, in a *ventral* position, are well developed proximally on the distal stele. Distally from this, smaller groups are intercalated, usually replacing a whole plate by two or three smaller ones, and near the distal end of the stele the plate arrangement becomes irregularly polygonal on all sides.

The proximal steles of both *Syringocrinus* and *Iowacystis* are tetramerous and do not vary greatly in overall form from other genera in the order except for the supposedly more "primitive" polymerous forms, e.g., *Dendrocystites*.

Carpoids having a longitudinally differentiated stele, but no styloid or stylocone are placed in the superorder Astylophora which contains only one order, the Soluta.⁵

Order SOLUTA Jaekel, 1900, 1921; Gill and Caster, 1960

Gill and Caster (1960, p. 15) diagnosed the order (emending Jaekel) as follows:

Polyplacate heterostele (homoistele and astylophorous) echinoderms in which no fixed plan of thecal plate organization was achieved. A single, tetraserial brachiole is eccentrically developed distally on the theca.

Four families of this order are recognized in this study: (1) *Dendrocystitidae* Bassler, 1938 (= *Dendrocystidae* Bather, 1913) are exclusively of Ordovician age in Europe. Two known possible exceptions are first, some rather questionable "stem" fragments from the Lower Ordovician of Korea, reported by Kobayashi, 1934. After examining his illustrations, the authors are reasonably certain that these are neither carpoid stele nor cystoid column plates. Secondly, a poorly preserved partial stele from the Upper Cambrian of Nevada, reported by Ubaghs, 1963, may belong to this taxon. (2) *Rutroclypeidae* Gill and Caster, 1960, are found in the

⁵For a discussion of carpoid classification see Gill and Caster (1960, pp. 7-11).

Lower Devonian of Australia and Europe. (3) The *Iowacystidae* Gill and Caster, 1960, which are here further considered, and (4) the *Syringocrinidae*, *nov.*, are known only from the Middle and Upper Trenton (Ordovician) of North America.

Examination of the North American families shows that they have a somewhat more highly organized and standardized thecal plate pattern, especially in the *Iowacystidae*, than do other representatives of the *Soluta*. Both exhibit definite marginal plates, as opposed to the other solute families which show (except at the base of the stele) only many undifferentiated plates along their edges.

The ventral thecal plates in *Iowacystis* show definite bilateral symmetrical arrangement, whereas *Syringocrinus*, although possessing a bilaterally symmetrical theca, does not exhibit symmetrical plate arrangement. However, the plate pattern is, in all probability, essentially standardized. The well-defined bilaterally symmetrical thecae of the North American genera contrast with the condition in the dendrocystids which show no definite thecal forms except that they tend to be subtriangular in preserved outline and somewhat flattened. The *Rutroclypeidae*, like the *Syringocrinidae*, have a bilateral, (nearly circular) theca, but show no definite symmetrical plate arrangement on either face.

The single brachium of the North American forms is not so well known as to plate composition or length as the European or Australian genera which are far commoner and hence well understood. However, the small remnants of the brachiole seen on *Iowacystis* do not seem to deviate greatly, at least in the known basal region, from the arm of *Dendrocystites*. Two series of paired plates are visible: an inner (erectile?) set, which delimits a subvective groove, and an outer set of larger semicircular alternating plates that partly encase the former series. Internally the floor of the food groove was located at the juncture of the larger series and was presumably exposed by the opening of the lesser plates. The brachiole of *Syringocrinus* will be discussed below.

The North American families have somewhat inflated thecae, perhaps more so than Eastern Hemisphere forms. *Syringocrinus* was probably globose and *Iowacystis*, albeit flattened, depressed, must have had a relatively thicker theca than forms of the other two families by virtue of the deep marginals. The marginals on

the former genus are elevated, and the holotype of *S. sinclairi* (described below) clearly shows the upper surface sunken beneath the dorsal rim of the marginals. In all probability this thecal surface in life arched inflatedly above the upper layer of the marginals. The non-American solutes generally appear to exhibit depressed thecae, though to what extent this is a preservational phenomenon, especially in the dendrocystitids, one cannot be sure.

Steles in the North American forms vary somewhat from the other two families in form and perhaps somewhat also in function.

Family **SYRINGOCRINIDAE** Parsley and Caster, nov.

The family can be diagnosed as follows: Soluta with bilaterally symmetrical theca but with the plates not evenly bilaterally arranged; theca somewhat depressed; boundary marginal plates, and surfaced by many polygonal somatic plates of relatively large size, and not standardized in number or arrangement; upper and lower thecal surfaces are distinct; arm similar to the arms of other solute genera; proximal stele tetramerous, symmetrical; distal stele asymmetrical, the left series of plates larger than the right series; the first series with nodes and flanges, the second with ventral sutural ridges; a dorsal series of intercalated plates is proximally located in the distal stele (median stele region).

Range.—Known only from the Middle Ordovician of Quebec and Ontario.

The family is monogenerie; for the present there seems to be little need to distinguish familial and generic taxobases, although the traits given in the diagnosis above appear to be of fundamental familial significance.

The establishment of differentiated upper and lower surfaces, each with characteristic plate size and prosopon⁶, together with the curious asymmetry and nodose structures of the stele, mark this as an advanced and distinct solute family.

Genus **SYRINGOCRINUS** Billings, 1859

1859. *Syringocrinus* Billings, Geol. Sur. Canada, Canadian Or-

⁶For use of the term see Gill, 1949.

ganic Remains, Dec. 4, pp. 65-66, pl. 10, fig. 14. See type species below for synonymy.

The genus is redefined and diagnosed as follows: theca bilaterally symmetrical, inflated-depressed; plates not evenly bilaterally paired, marginal plates large (probably 13 in number); ventral surface with large polygonal plates bearing pebbly prosopon; dorsal theca with many small polygonal plates, each with an irregular boss in its mid-area; brachiole tetraserial, emergent from anterior left upper surface just slightly to the left of the thecal midline; proximal stele composed of approximately 12 imbricating, tetramerous segments; distal stele asymmetrical; left plates broader and shorter than right plates, with dorso-ventrally orientated elongate nodes on proximal portion of distal stele, also with raised sutural flanges terminating in a ventro-distal "plowshare-like" flange, present to nearly distal end of series; right series of plates with low ventral ridges along distal margins of each plate; proximal portion of distal stele (median stele region) with three to five dorsal intercalated (sagittal) plates between right and left series, all tightly fused into a rigid zone, the dendrostyloid.

Range.—Middle and Upper Trentonian of Ontario and Quebec.

Type species.—*Syringocrinus paradoxicus* Billings, 1859.

Discussion.—Billings (1859, p. 65) conceived of *Syringocrinus paradoxicus* as being composed of four series of polygonal plates (two series visible in the single known specimen, the other two buried in the matrix) which he thought constituted a "tube-like fossil," which was narrow at one end due to flattening by pressure, and somewhat larger at the other end, possibly due to separation of the plates. At one end of the body there was . . . "an additional part, composed of numerous small, elongated, irregular plates placed transversely" (*ibid.*, p. 66), this being the badly crushed proximal stele of the specimen. He supposed that this fossil was part of a hitherto undescribed crinoid; hence the generic name.

Miller (1889, p. 285) commented on the genus as follows: "Founded, possibly, on the fragment of a ventral sac: at all events not a well-characterized genus." In a similar vein Wachsmuth and Springer (1881, p. 41) listed the genus as a crinoid "imperfectly

known" and the species (*ibid.*, p. 41) "*Syringocrinus paradoxus*" as "parts of the arms (?)." .

Bather (1900, p. 48) recognized the carpoid nature of Billings' specimen and grouped *Syringocrinus* with "*Dendrocystis*" inferring that the two were synonymous. At the same time, he saw a close resemblance between "*Dendrocystis*" and the genus *Cigara* Barrande, 1887, of Cambrian age from Bohemia. This polyplacoid conical echinoderm is made up of elongated, transversely oriented polygonal plates. There is admittedly some slight resemblance to the proximal stele of *Dendrocystites*; however, it is now presumed that this problematic genus belongs in the Eocrinoidea rather than the Carpoidea.

Bather (1913) continued to identify *Syringocrinus* with "*Dendrocystis*" though with some uncertainty, and assigned *Syringocrinus paradoxicus* to "*Dendrocystis* (?) *paradoxica*" [Bather (1900) substituted the spelling *Dendrocystis* for *Dendrocystites* Barrande, (1887)]. He recognized, of course, that if the American and European genera were identical, *Dendrocystites* would be a junior synonym of *Syringocrinus*. Bather (1928, p. 705) after examining and further preparing the specimen of *Syringocrinus paradoxicus* Billings, made a fairly detailed redescription. He noted for the first time the presence of bilateral asymmetry, the left series of shorter plates bearing nodes and flanges, while the opposed right plates were smooth, longer, and narrower. He remained uncertain as to the identity of *Syringocrinus*, and hence the questionmark after the generic name. Bather lamented that if the two were synonymous, the lesser known Canadian species would, by priority, be the proper name and the widely known *Dendrocystites* would be invalidated. The specimen, at the time he examined it, was minus part of the distal stele figured by Billings (1859). This has probably been lost.

Bassler (1938) followed Bather's lead and placed the two genera in synonymy. However, he employed *Dendrocystites* rather than *Syringocrinus* for the genus.

Chauvel (1941, p. 171) recognized *Syringocrinus* as a valid genus; however, in a stratigraphic chart (*idem.*, p. 241) apparently based in part on one by Bather (1913, p. 372), he retained Bather's name "*Dendrocystis*" for both *Syringocrinus* and *Iowacystis*.

Wilson (1946, p. 8) followed Bather's suppression of *Syringocrinus* and listed several new localities for *Dendrocystites paradoxicus*; two (in the Cobourg beds, Philemon Island, Quebec, and near Caseburn, Ontario) extend its range into the Upper Trentonian. Her other new locality (Sherman Falls beds, on the east side of Governor Bay, Ontario) lies in the Middle Trenton.

Gill and Caster (1960, pp. 17-20) recognized *Syringocrinus* as a valid genus on the basis of its distinctive morphology. They stressed the importance of stele traits in solute taxonomy.

***Syringocrinus paradoxicus* Billings**

Pl. 16, fig. 3

1859. *Syringocrinus paradoxicus* Billings, On the Crinoideae of the Lower Silurian Rocks of Canada: Canadian Organic Remains, Dec. 4, Geol. Sur. Canada, pp. 65-66, pl. 10, fig. 14.
1877. *Syringocrinus paradoxicus* Billings, Miller, The American Paleozoic Fossils: A Catalogue of the Genera and Species, Cincinnati, Ohio, p. 92.
1882. *Syringocrinus "paradoxus"* Billings, Wachsmuth, and Springer, Revision of the Palaeocrinoidea, Acad. Nat. Sci. Philadelphia, Proc. for 1881, p. 411.
1889. *Syringocrinus paradoxicus* Billings, Miller, North American Geology and Paleontology, Cincinnati, Ohio, p. 285.
1900. "*Dendrocystis paradoxus*" (Billings), Bather, in Lancaster, A Treatise on Zoology, Pt. 3, The Echinodermata, London, p. 48.
1913. "*Dendrocystis (?) paradoxica* (Billings), Bather, Caradocian Cystidea from Girvan, Roy. Soc. Edinburgh, Trans., vol. 49, pt. 2, No. 6, pp. 371, 372, 397, 398, fig. 13, p. 396.
1913. *Syringocrinus [paradoxicus]* Billings, Springer, in Zittel and Eastman, Text-Book of Paleontology, New York, vol. 1, p. 151.
1915. *Dendrocystites? "paradoxica"* (Billings), Bassler, Bibliographic Index of American Ordovician and Silurian Fossils, United States Nat. Mus., Bull. 92, vol. 1, p. 398.
1921. *Syringocrinus [paradoxicus]* Billings, Jaekel, Phylogenie und System der Pelmatozoen, Pal. Zeit., Bd. 3, p. 124.
1925. *Dendrocystites? "paradoxica"* (Billings), Nicoles, Index to Paleontology, (Geological Publications 1847-1916), Geol. Sur. Canada, p. 90.
1928. "*Dendrocystis (?) paradoxica*" (Billings), Bather, *Dendrocystis* in North America, Canada Dept. Mines, Geol. Sur., Bull. 49, (Geol. Ser. 48, Contrib. Canadian Paleont.), pp. 7-8.
1938. *Dendrocystites [paradoxicus]* (Billings), Bassler, Pelmatozoa Palaeozoica, Fossilium Catalogus, 1: Animalia, Pars 83, pp. 9, 85.
1940. *Syringocrinus [paradoxicus]* Billings, Hecker, Ordovician and Devonian Echinoderms, Acad. Sci. Union of Soviet Socialist Republics, Pal. Inst., Trav., vol. 9, pp. 20, 62.
1941. *Syringocrinus [paradoxicus]* Billings, Chauvel, Recherches sur les Cystoïdes et les Carpoïdes Américains, Société Géologique et Mineralogique de Bretagne, Mém., T. 5, pp. 171, 241.
1943. *Dendrocystites paradoxicus* (Billings), Bassler, and Moody, Biblio-

- graphic and Faunal Index of Paleozoic Pelmatozoan Echinoderms, Geol. Soc. America, Spec. Paper, No. 45, pp. 4, 149, 150, 192.
1945. "*Dendrocystis* (?) "*paradoxicus*" (Billings), Ragn  ll, Non-Crinoid Pelmatozoa from the Paleozoic of Sweden, Lunds Geol. Min. Inst., Medd., Bd. 108, p. 195.
1946. *Dendrocystites?* *paradoxicus* (Billings), Wilson, Echinodermata of the Ottawa-St. Lawrence Lowland, Canada Dept. Mines Res., Geol. Sur. Bull., No. 4, pp. 3, 8.
1960. *Syringocrinus paradoxicus* Billings, Gill and Caster, Carpoide Echinoderms from the Silurian and Devonian of Australia, Bull. Amer. Paleont., vol. 41, No. 185, pp. 17-20.
1963. *Syringocrinus paradoxicus* Billings, Ubaghs, *Cothurnocystis* Bather, *Phyllocystis* Thorall, and an undetermined member of the Order Soluta (Echinodermata Carpoidea) in the uppermost Cambrian of Nevada, Jour. Paleont. vol. 37, vol. 6, p. 1141.

A single specimen from the Middle Ordovician, Sherman Falls beds at Beauport, Quebec, was described by Billings in 1859. It consists of a badly crushed proximal stele and part of the dendrostyloid, the latter being but little deformed. The stele is compressed on the bedding surface of the calcareous shale with its left⁷ side exposed. The distal stele plates on the right side of the specimen pertain to a continuous dorsal (sagittal) series of dendrostyloid plates homologous to those seen in *Syringocrinus sinclairi*, *sp. nov.*, below.

The proximal stele of the specimen was depressed in life and made up of approximately twelve imbricating tetramerous segments. The exact number is not discernible due to poor preservation. The dorsal and ventral sutures are probably like those in *Syringocrinus sinclairi*, *i.e.*, these zigzag sutures reflect a merous dovetailing reminiscent of some *Dendrocystoides scotia* [Bather (1913), p. 374, fig. 9]. These interdigitating plates probably afforded considerable mobility.

Transition from the proximal stele to the dendrostyloid is poorly preserved, and some of the left proximal dendrostyloid plates are badly deformed. However, the dendrostyloid zone is composed of three distinct series of plates: a disparate right and left series and a dorsal series. The dorsal surface of the dendrostyloid

⁷Right and left refer to the animal in its "in life" orientation. Similarly the thecal surface which lies against the substrate in life is the ventral, lower, or aboral surface and the opposite surface is the dorsal, upper adoral, or oral. The upper and lower surfaces in the American solutes are specialized in the same manner as in the Mitrates where Caster (1952) used carapace and plastron, respectively, for these surfaces. These terms could also be used here. See Bather (1930) and Caster (1952, p. 10).

was transversely arched, suboval in section, both sides being nearly vertical and the venter flattened. The plates of the left flank series are wider and shorter than those of the dorsal series. The four (?) most proximal plates in the left series are nearly square in outline and have in their mid-portion a prominent dorso-ventrally elongated node. They also bear low sutural flanges paralleling the distal suture in the ventro-lateral portion of the plate. More distal plates in this series retain the nodes but the sutural flanges rise sharply from near the mid-point of the dorso-ventral node and extend ventro-distally across the rest of the plate; forming a plow-share-like extension in the ventro-distal corner of the plate. (This differs from *Syringocrinus sinclairi*, *sp. nov.*, where the sutural flange closely parallels the suture, gradually rising to form the extended flange.)

Unfortunately, the right flank series is concealed. Some extrapolation from the right side features of the dendrostyloid in the new species *Syringocrinus sinclairi*, below, has been employed in interpreting the visible plates of this specimen.

A dorsal series of contiguous plates, the sagittals, intercalates between the right and left series. The total number of these is unknown, five can be made out. Possibly, as in the new species, more distal isolated dorsal plates may be present. [Billings (1859, pl. 10, fig. 14) did not illustrate any isolated plates in the distal portion of the holotype (part of which is now lost) and from his drawing it appears to have preserved the dorsal surface.] The dorsal series is inserted in the proximal part of the distal stele which is the dendrostyloid, or median stele zone, and may have extended, as in the new species, on to the rest of the distal stele as isolated plates.

The dorsal stele plates are without prosopon except for the most proximal one which has three small circular nodes. This plate is small and more or less hexagonal in outline. The rest of the plates are elongated along the stele axis. The second and third in the series bear each a ventral-facing lobation that intercalates for a short distance between contiguous plates of the left series. There is one small, irregular plate (and perhaps several more as suggested by the preservation) between the first two dorsal plates and the left series. The one such that is visible is intercalated mostly be-

tween the dorsals and only slightly between the laterals. There is probably little reason to expect similar or paired counterparts of these minor intercalary plates between the dorsal and right series.

Gill and Caster (1960, p. 19) stated erroneously that “. . . all of the proximal stele plates revealed in the holotype, bear transverse elevated bosses or bars of unique character.”

Their observation was based on a photograph of the poorly prepared specimen. Subsequent preparation and cleaning shows that the only prosopon on the proximal stele is a fine granulation of the sort seen generally over the surface of *Syringocrinus sinclairi*.

The small polygonal plates associated with the *Syringocrinus paradoxicus* stele mentioned by Bather (1928, p. 7) and mentioned again by Gill and Caster (1960, p. 17), as disassociated thecal plates are too few and of too indistinct a character definitely to associate them with the holotype.

As indicated above, part of the holotype has been lost. Billings (1859, pl. 10, fig. 14) illustrated a portion of the terminal zone of the distal stele. Bather (1928, p. 7) noted that the specimen at the time he examined it was minus this extremity. Gill and Caster (1960, pp. 17-18) indicated that the complete distal stele (including what is here called the dendrostyloid) was at least four times as long as the proximal portion.

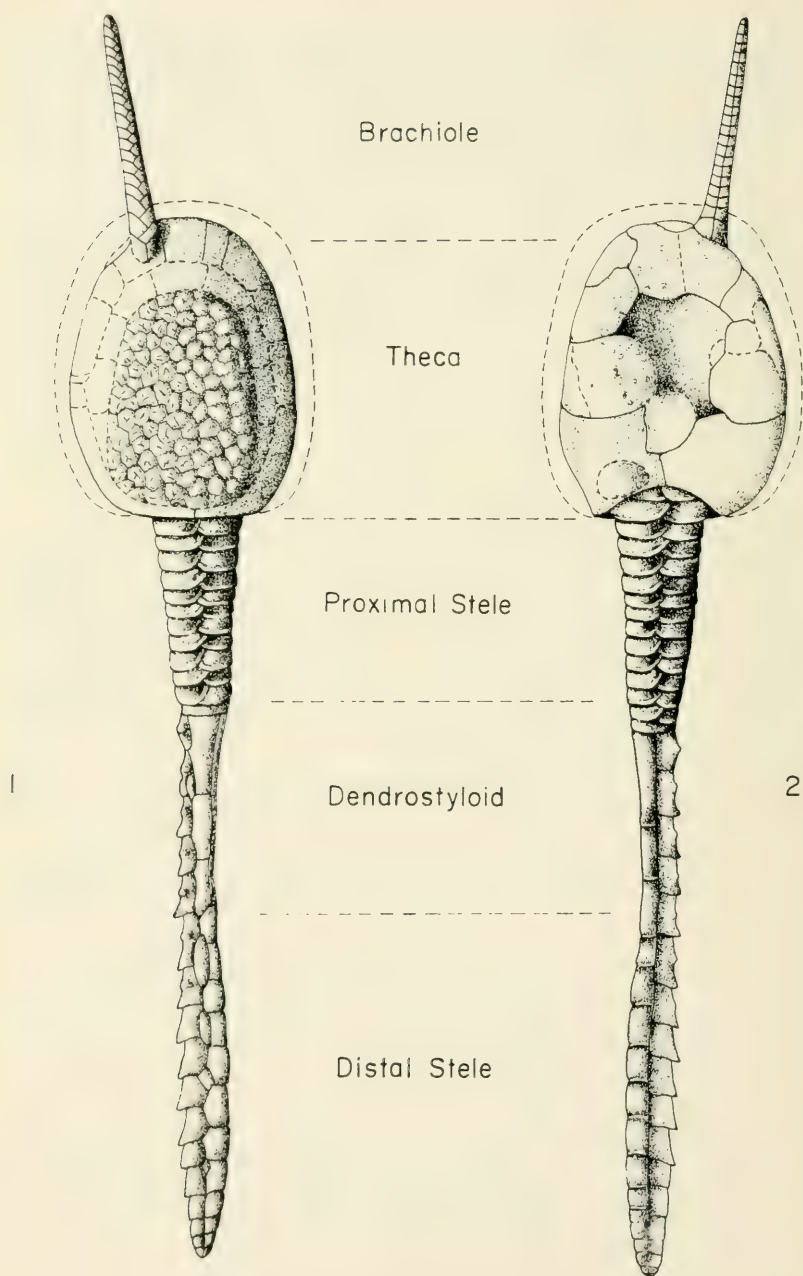
Occurrence.—Middle Ordovician, Sherman Falls beds, Beaufort, Quebec.

Comparisons.—*Syringocrinus paradoxicus* is distinguished from *Syringocrinus sinclairi* Parsley and Caster, *sp. nov.*, by the following traits:

- (1) The nature of the sutural flange on the left series differs in the two species and is discussed under both species descriptions.
- (2) The former species has at least five dorsal plates in the dendrostyloid, the latter only three.

Syringocrinus sinclairi Parsley and Caster, *sp. nov.* Pl. 16,
figs. 1, 2, 4-9, 11; Text-figs. 1-4

This new species of *Syringocrinus* is based on the holotype and eight paratypes which range from nearly complete specimens to



Text-figs. 1, 2. Explanation page 123

portions of the stele. It is the most extensive Soluta material found in the Americas. There are two complete thecae and four others in varying degrees of completeness. One of the poorest specimens, however, has a nearly complete brachiole. The plates are not well preserved, especially the dorsal ones, thus limiting our understanding of their nature.

The stele of this new species clearly pertains to the same genus as *Syringocrinus paradoxicus* Billings, above, and the added features of the theca and subvective area well document the distinctness of the genus among the Soluta. The morphobases for the new family Syringocrinidae also largely derive from this material.

Theca.—The theca is nearly bilaterally symmetrical in plan, having a more or less subtriangular to squared-oval outline. See Text-figs. 1, 2. The greatest width is about one-third the distance distad of the proximal plane. Ventrally the proximal margin is broadly excavated for stele attachment (Text-fig. 2). The brachiole is attached to the anterior dorsal side of the theca on the left side. The theca was essentially rigid and somewhat inflated. The dorsal surface was broadly arched and the ventral one partly concave. Thus again recalling the “carapace” and “plastron” of the Mitrata.

As in the Mitrata, it is convenient to distinguish here between the marginal plates which extend onto both dorsal and ventral surfaces, and the somatic plates, which are confined by the marginals to the dorsal and ventral surfaces. There are few ventral somatic plates, apparently all of relatively large size and many dorsal somatics, which, although imperfectly known, appear to consist of an antero-lateral circlet of larger plates and a larger central area of much smaller plates which occupy perhaps half of the dorsal surface.

Text-fig. 1, 2. Two aspects of *Syringocrinus sinclairi* Parsley and Caster, *sp. nov.* 1. A reconstruction of the dorsal surface based on the holotype (GSC 17520) and paratypes (I, GSC 17521; V, GSC 17522b; VI, GSC 17523; VIII, GSC 17525). Note the imbricating proximal stele, dorsal plates, and nodes and flanges on the left series of the dendrostyloid. Broken lines around the theca indicate a more probable relative size of the theca; on the theca itself they indicate problematic sutures. 2. A reconstruction of the ventral surface based on the holotype (GSC 17520) and paratypes (I, GSC 17521; II, GSC 17521a; VII, GSC 17524; VIII, GSC 17525). Note the ventral thecal plate arrangement (see fig. 3), ventral ridges on the right series of stele plates, serrate left series of stele plates and absence of sagittal intercalate plates.

The marginals are for the most part paired; they form a rigidly fused border of the theca and participate as well in covering both dorsal and ventral surfaces. The front margin (distal margin) is composed of three plates: the distal marginal, *dm*, and the anterior marginal pair, *am*; the lateral margin is comprised of three unequally paired plates: anterior lateral marginals, *alm*, median lateral marginals, *mlm*, and posterior lateral marginals, *plm*; and the proximal border is composed of two large, equal plates: the posterior or proximal marginals, *pm*.

All of the lateral marginals and the posterior marginals sharply geniculate at the lateral perimeter of the theca; the anterior marginals are arcuate on the distal perimeter. The shell substance of the marginals is thick and especially so at the zone of geniculation. In the ensuing analysis of the theca and stele plates reference should be made to Text-figs. 11-14.

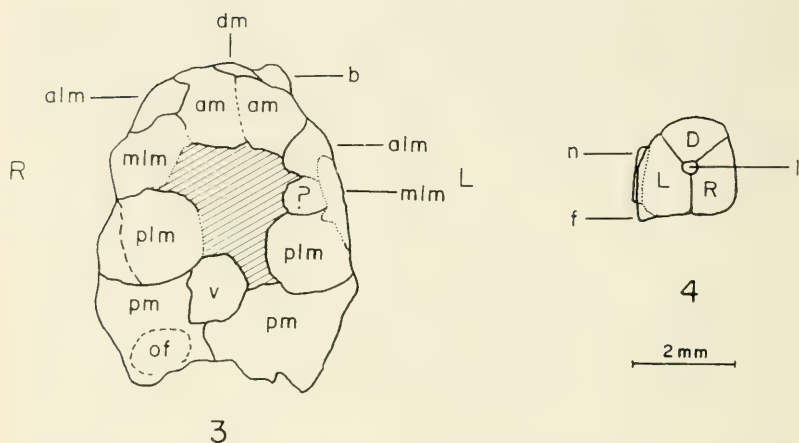
The most anterior plate is the distal marginal (*dm*) which is essentially dorsal in development and is alternative in position with the anterior marginals (*am*). This plate is unique among the marginals in not forming part of the ventral surface but forms much of the distal median margin and extends dorsally as a smooth, moderately steeply curved wall, as do the rest of the marginals. The distal marginal is in contact with the right base of the arm (*b*). The remainder of the arm base is in contact with the right anterior marginal (*am*) which is the true plate of emergence. The distal marginal simply overlaps this plate near the subvective organ and is not excavated to accommodate the arm.

The anterior marginals (*am*) are nearly equal in size but somewhat dissimilar in shape. They meet on the sagittal line ventrally and are separated dorsally by the distal marginal plate. Although the ventral surface expression of this pair is subequal, they become disparate dorsally, where the left expression, bearing the brachiole, is nearly twice as broad as the right one. The ventral axial suture between the pair is poorly defined and presumably reflects a tight fusion. The right anterior marginal has a deep reentrant on the ventral expression of its right anterior side for the accommodation of the irregular right anterior lateral marginal (*alm*). The left counterpart, which is the brachiole bearer, forms

an irregular but fairly straight suture with its adjacent left anterior lateral marginal. The antero-lateral and lateral sutures of both anterior marginal plates extend dorsally from the ventral surface as essentially straight lines. Lateral and dorsal regularity of all marginal sutures is the rule.

The anterior lateral plates (*alm*) are an unequal pair. On the ventral surface the left of these extends to the somatic zone as a nearly rectangular tongue, which may bear an arcuate reentrant on its proximal suture for the insertion of a lobe of the adjacent median lateral stele (see Text-fig. 3). On the dorsal surface the plate continues essentially quadrately. The opposite anterior lateral plate is ventrally intercalary in position between the contiguous anterior median and median lateral marginal and fails to attain the somatic zone, the anterior median and median lateral plates having a common interior suture for some distance. On the dorsal surface the plate broadly extends over the antero-lateral thecal area.

Proximal to these plates lie the greatly disparate pair of median lateral marginals (*mlm*). The right, larger of these, extends from the ventral somatic zone around to the thecal margin to occupy considerable quadrate area of the dorsal surface. As indicated above, it sutures with the right anterior median on the ventral surface. The left element, on the other hand, seems to have an intercalary configuration (recalling the ventral aspect of the right *alm* plate) and may not attain the somatic zone. This problem devolves in the nature of a quadrate area (marked with "?" on the finding diagram, Text-fig. 3), some of the boundaries of which are unclear. If this small plate is somatic, it is laterally exerted far beyond the general somatic confines; it may be a linguete inward extension of the plate under discussion (*mlm*), as it may be a distal lobate extension of the posterior lateral median plate. The last explanation is presently preferred largely on the basis of the clear relationships between *mlm*, *alm* and *am* plates on the opposite side where the problem of distal thecal narrowing seems to have been met by exertion of the *alm* plate and contiguity on the venter of the *am* and *mlm* plates. That this condition on the left side occurs within the median series, rather than further forward as on the right side, may correlate with the asymmetry inherent in the possession of a bi-



Text-figs. 3, 4. *Syringocrinus sinclairi* Parsley and Caster, *sp. nov.*, terminology of various plates. 3. Plate pattern of the concave ventral surface of *Syringocrinus sinclairi*, *sp. nov.*, based on paratype No. I (GSC 17521); *alm*, anterior lateral marginal; *am*, anterior marginal; *b*, arm, or "brachiole"; *dm*, distal marginal; *mlm*, median lateral marginal; *of*, opercular flap; *plm*, posterior lateral marginal; *pm*, proximal marginal. Dotted lines, approximate suture lines; broken lines, problematic sutures. 4. A generalized cross-section of the dendrostyloid of *Syringocrinus sinclairi*, *sp. nov.* *D*, dorsal plate; *L*, left plate; *R*, right plate; *f*, sutural flange; *l*, lumen; *n*, node.

laterally adjusted theca possessing a single brachiole on the left side.⁸

The dorsal expression of the left median lateral marginal is broadly quadrate.

The posterior lateral marginals (*plm*) are large polygonal plates which are fairly equal in size and similar in outline. Their major development is ventral. The marginal component of the left plate is limited due to the proximal elongation of the median lateral marginal, while its counterpart has a marginal component nearly equal in length to its ventral diameter. The ventral surface of the right plate has a low, circular, central boss surrounded by concentrically arranged, pebbly prosopon. Although it can not

⁸The zygomorphy implied in this analysis and nomenclature may be an illusion, and most certainly no homology with the Mitrata is implied in employing similar plate names in the two orders. It is a striking example of parallel development which creates the remarkable analogues in New World solutes and placocystid mitrate thecae.

be demonstrated on the available specimens, the left plate is probably bossed also. There is some indication (*e.g.*, the broken line crossing this plate in Text-fig. 3) that the right plate may actually be divided by an arcuate suture extending from the extreme distal margin to a point about one-third of the plate width in from the margin on its distal suture. This line may merely be a fracture.

The proximal marginals (*plm*), like the foregoing pair, are largely ventral in development, but meet at the sagittal line on both surfaces on the ventral axial line; the pair are deeply excavated for the reception of a large subtrigonal somatic median plate. On the dorsum the proximal marginals are a narrowly fringing frame to the proximal somatic area and are apparently directly in contact to the area of small somatic plates, *sans* intervening circlet of larger somatic plates which occur laterally and distally. On the venter the proximal margin is excavated crescentically for the insertion and flexing of the proximal stele. Presumably the stele muscles were mainly fixed to the proximal marginal plates, although no inner plates, notchings or buttresses for such attachment have been seen.

In the posterior area of the right proximal marginal there is an oval, inflated area, similar to an ostracod valve in outline. Pebbly prosopon also sets it off from the enclosing marginal. This structure may be an opercular flap (*of*) and was possibly erectile along the proximal margin. If this is an anal plate, it suggests a diagonal course of the alimentary system similar to that which probably existed in *Iowacystis*. If the "flap" is a reality and the interpretation correct, its presence on the ventral face of the right posterior marginal obviates the use of the usual solutan terms for the two thecal surfaces, *i.e.*, anal (upper) and antianal (lower) in this genus.

As can be seen in Text-figures 2 and 3, the area of the ventral somatic plates is relatively small and irregular. Of particularly intriguing portent is the reentrant of the space adjacent to the right median lateral marginal (*mlm*) plate. This suggests the presence of a large somatic plate in this area without any indication of a matching plate on the left side—unless the "?" plate hitherto discussed is of such a nature. This right asymmetry of the somatic

space is reminiscent of the Mitrata somatic area where the "anomalcystid" unpaired plate occupies the same position.

Clearly the somatic area was occupied by relatively few large plates, which may have lacked zygomorphy throughout. Only one undoubted somatic plate (and perhaps part of another) is preserved.

All of the plates on the ventral surface have an even, rounded, granular to pebbly prosopon which is arranged in arcuate rows, or in some cases is definitely concentric with the plate margin. The grain is larger toward the center of the plates and becomes quite fine near the margins. This suggests peripheral increment in plate growth.

The dorsal surface of the theca, as adduced in the main from the holotype and the arm-bearing paratype V, is restored in Text-fig. 1, but undoubtedly this will be significantly modified when better material is known. It seems that a circlet of large somatic plates borders the marginals on the sides and distal region; these are termed the outer somatics. Inside this ring, and constituting most of the carapace, many small polygonal plates appear to constitute the covering. The outer somatics alternate with the marginals and rise above them in height toward the axial line. (This series, together with the inner thecal plates, probably formed an arched upper surface.) The inner periphery of the outer somatic plates, from what can be deduced from the fragmentary evidence, formed a subrectangular area which is occupied by the inner thecal plates. Prosopon on this outer series is limited to the usual pebbly grain seen on other plates; however, no discernible pattern was observed.

The "inner somatic plates" are polygonal, tending to be hexagonal, pentagonal, rounded or oval. Average diameter of these plates is one to two millimeters. The edges of some are bounded by a low, narrow ridge from the top of which the edge curves sharply, forming a shallowly arcuate to straight-sided lateral wall. Otherwise the margin is either slightly thickened or unaltered. These plates were loosely articulated in contrast with the tight fusion of all the other thecal plates. This dorsal flexibility may correlate with a pumping action of the gut, a process with which the order is commonly credited, but without much substantiation.

The center of each inner somatic plate is elevated in an irregular boss primarily made up of radiating or elongated ridges with irregularly divergent diverticulations of unequal length and width. (Again a certain amount of distortion is present on available specimens.) There is more than superficial resemblance between these bosses and those of the upper, more proximal plates of *Dendrocystites sedgwicki* Barrande (1887, pl. 26, figs. 1, 7-9; pl. 27, fig. 6; Bather, 1913, pl. 1, fig. 6) which have definite rays or ridges extending from the bosses to the plate corners. Bosses on the plates of *Heckericystis kuckersiana* (Hecker), 1940, p. 24, figs. 14, 15) are similar to the nodular plates in the central portion of *Dendrocystites sedgwicki*, i.e., they lack the radiating ridges. Australian rutroclypeids possess small, rounded, highly elevated bosses called spines by Gill and Caster (1960, pp. 24-26). These authors are probably correct in viewing spines, bosses, and the like as a recurring phenomenon in solute evolution. However, in the possibly closely related *Dendrocystites* and *Heckericystis* the prosoponic bosses may well be homologous. In *Syringocrinus sinclairi* the number of inner somatic plates is not known, but extrapolating from the 20 or so that can be seen on the holotype, it is estimated that about 40 were present. This is the approximated number reported by Thomas and Ladd (1926, p. 8) for the somatic plates on the upper surface of *Iowacystis*.

The proximal margin is believed to narrow toward the midline and appears to be made up entirely of the upper extension of the two proximal marginals. This proximal thecal make-up of only two large plates is unique to the Soluta and forms a rigid "proximal girdle."

The arm is attached near the dorsal distal median edge of the left anterior marginal on the left corner of the theca (see Text-fig. 1). The distal base of the brachiole is marginal in position, but most of the structure emerges from the dorsal surface. The brachiole is composed apparently of four rows of plates. The inner (inferior) series of ossicles are paired and regularly opposite. They are twice as long and about one and one-half times as wide as the paired alternating outside (superior) rows. The inferior paired brachioles appear to bear a shallow U-shaped ambulacral groove. The alternating superior plates fitted to form an erectile cover to

the groove and constitute virtually the entire dorsal surface of the arm. In life, when the animal was feeding, these plates would naturally spread to expose the ciliated groove, as in the other *Soluta* (e.g., Bather, 1913, p. 369, par. 72). He (*idem.*, p. 375, par. 65) claimed that this is the condition in all the dendrocystitid brachioles. The "mouth" is not visible but was most likely located at the base of the subvective ambulacral groove, beneath the arm-bearing anterior marginal plate. The single specimen of *Syringocrinus* brachiole is incomplete but has 20 pairs of larger plates and approximately 10 pairs of the smaller. The arm clearly tapers but at a lesser angle than in other *Soluta*. The resultant arm, as indicated by projection of the tapering, is relatively longer and larger than that of any other known member of the order. The length as seen in restoration Text-figs. 1 and 2, approximates that of the theca and at its base is about one-half as wide as its supporting plate. In cross-section it is a compressed oval.

Stele.—The stele is conveniently divided into the proximal and distal stele. The latter is further divisible into the median stele, or dendrostyloid, and the "metastele".

The proximal stele is a broad, somewhat depressed area, attenuately trapezoidal in outline, tapering distally and truncating against the dendrostyloid. It is made up of approximately 12 (11-13) axially imbricating, tetramerous segments of which the component meres are opposed laterally, but which also alternately imbricate both dorsally and ventrally. This lateral alternating overlap of the meres gives the sagittal sutures a zigzag effect. Approximately half of each segmental ring is inserted beneath the adjacent proximal ring. Each mere on its outer surface is gently convex externally and bears a gentle ridge along the distal margin. On some meres, especially on the venter, a lesser ridge is present on the proximal exposed portion of a mere, just distal to the imbricate zone. This secondary ridge, however, is not universal on these meres and may be deformational. The thickest portion of each mere is along the distal margin accentuating the antero-posterior imbrication. The distal surfaces of the meres, and especially their dorsal and ventral expressions, are smooth and slightly concave. Proximally the meres grow thinner. The transverse, alternating imbrication along the sagittal suture is facilitated by adaxial smoothing

or bevelling of the internal imbricates. Clearly both the axial and sagittal imbrication with the correlated gliding surfaces bespeak mobility of the proximal stele. The lateral sutures lie in the plane of extension (*i.e.*, horizontal) midway between the dorsal and ventral sutures. The meres do not overlap here but simply abut. Distally located to each of these lateral sutures is a shallow rounded depression or notch formed by the divergence of the abutting meres near their distal margin. These notches probably facilitated movement in the plane of extension and correlates with the lateral imbrication of the dorsal and ventral surfaces. The last segment is more of a tetramerous ring, sagittal, imbrication is reduced or missing, and probably serves as a rigid abutment for the dendrostyloid.

Through fossilization the loosely articulated proximal stele tends to become somewhat elongated and depressed, *i.e.*, less imbricated. In life the cross-section would appear to have been a depressed oval, probably unevenly convex dorsally and flattened ventrally. Prosopon on this portion of the stele, in addition to the transverse ridges, consists of fine granulation, as in *Syringocrinus paradoxicus* Billings, but is limited to the external portions only. The interior articulating surfaces and lateral glide planes are presumed to be smooth. The integumentary attachment seats of the proximal stele rings are not known, but strong flexible strands were no doubt present in the living animal.

Internally this structure had a large lumen like other carroids. The organs occupying the space were probably mainly locomotor and dynamic. The nervous system and haemal system necessary to maintain these muscles, as well as various tissues in the stele, must have also traversed this lumen, as well as coelomic extensions of the thecal region.

The region of the stele in *Syringocrinus*, here termed *dendrostyloid* (generally referable to the median stele in other solutes), is an intermediate zone of apparently rigidly fused plates occupying the same relative position as the stylocone of the Cornuta and the styloid of the Mitrata. No homologies are inferred, although somewhat similar function presumably pertained. [See Gill and Caster (1960, pp. 9, 10), for a discussion of mesostele zones.]

In *Syringocrinus sinclairi* the dendrostyloid is composed of three series of azygous plates (not four as in the proximal stele).

These are termed the dorsal (or sagittal) left, and right series. These number 3, 5, 3 plates respectively. Rigidity and hence unitary function are the main basis for differentiating the middle zone as a dendrostyloid, for in plate arrangement and prosopon features the median and terminal stele progressively intergrade. Each of the five plates in the left series bears a conspicuous median node which is produced in the plane of extension to the left and also bears distally a nasute plowshare-like flange structure which overlaps the antero-ventral portion of each succeeding element. The nodes progressively disappear distally beyond the dendrostyloid, but the lateral "plowshares" continue to near the end of the stele.

The right series comprises three longer and narrower, unornamented plates which are not produced distally in the plane of extension. The three right plates occupy the same distance as the distance of the five on the left side. This series likewise continues throughout the distal stele but without ankylosis to adjacent plates beyond the limits of the dendrostyloid. Distad to the dendrostyloid, the right and left plates become progressively more evenly paired.

The plates of the dorsal series in the dendrostyloid are continuous and contiguous, alternating with the right and left series, and all tightly fused. The series continues disconnectedly and diminishing in size distally for some distance in the flexibly articulated distal stele zone.

The plates of the left series are more or less quadrilateral, some having supplementary small facets, but tending to be squares or parallelograms in dorsal or ventral outline. In cross-section the lateral plates are dorsally faceted for reception of the dorsal plates which are cuneiform in section. All of the plates in the dendrostyloid share the lumen (see Text-fig. 4). The sutures between the left lateral plates are distinct, essentially vertical, and, except for the most proximal plate of the series, the distal margins are rimmed by sutural flanges.

The sutural flange rises laterally along the distal margin, being evanescent at the dorsal angle. The flange tumescence increases in height until it reaches the ventro-distal corner which is extended sufficiently to give the corner its overhanging plowshare effect. On the ventral surface the flange forms a rounded ridge along the outer margin and originates from the outer proximal portion of

the plate. The rest of the undersurface of the plate (and the stele as well, except as indicated below) is flat. When viewed either dorsally or ventrally the left margin of the whole distal stele (including the dendrostyloid) has a distinctly serrated appearance.

The five left plates of the dendrostyloid and the two adjacent ones of the distal stele have on each a distinct mid-plate, elongate node which nearly extends the height of the plate and spreads approximately one-fifth of its length. The nodes vary in their individual elevation from low rises to sharply defined ridges nearly equal to the sutural flanges in their protrusion. One paratype (No. GSC 17525) shows these nodes dividing near the dorsal suture, producing a "Y" shaped ridge. This is seen on the sixth and seventh plate.

The dorsal corners of the plates are rounded or faceted to form a reentrant for receiving a cusplike lobation of the adjacent dorsal plate. On the ventral surface, the suture between the right and left series of plates is straight and near the sagittal line. The left proximal plates of the dendrostyloid are somewhat less arched than the distal ones.

The right series of plates in the dendrostyloid comprises three elongate, low vaulted, essentially unornamented plates which occupy the same axial distance as the five plates on the left side. In origin these may be compound plates but show no signs of the compounding. These plates are confluent, syzygiously sutured, and special wetting techniques have been required to discern sutural evidence. The first of these sutures lies opposite the mid-area of the third plate in the left series (see Text-fig. 1). This is followed in the right series by a shorter pentagonal plate whose distal suture lies opposite the mid-point of the fourth plate of the left series. The last of these three plates is long and its distal suture roughly corresponds with the distal suture of the fifth left series plate, and these two sutures, together with that of the third dorsal plate, delimit the dendrostyloid from the distal stele.

The dorsal sutures of the right series in the dendrostyloid are undulatory or subangularly zigzag for accommodating the essentially alternating dorsal series of three plates. These zigzag sutures between dorsal and right series are also syzygiously joined.

Distal to the third plate in the right series is a small distal stele

plate, pentagonal in plan, whose proximal and dorsal sutures appear to be ankylosed in the dendrostyloid manner, but its distal suture is wide like those of the rest of the distal stele. This transitional plate also marks the beginning of the widening and flattening of the distal stele.

The continuous dorsal series in the dendrostyloid is composed of three long smooth plates. The common longitudinal axis of which bears distally away from the median plane to the right. The upper surface of these plates is somewhat elevated and rounded in section. On both right and left ventral sides serrate lobations of these plates extend into the reentrants between the plates of the other two series. They nearly alternate with the left series. In outline these plates are elongate and they diminish in length and width distally.

As in *Syringocrinus paradoxicus* there is one (and perhaps more) small polygonal plate intercalated between the first and second dorsal plates and a reentrant in the left series.

The distal stele is depressed and spatulate in outline and differs from the dendrostyloid in that the right and left series of plates are paired and progressively come to match in size while shifting from an alternate to an opposite position. The dorsal series of plates continues here as a series of low isolated plates which decrease in size and change in shape from elongate to lozenge-shape distally and are progressively more widely spaced in that direction.

The left series is much the same as in the dendrostyloid except that it progressively loses the nodes and the ventral ridges of the flanges. Instead, the under surface of the series is planar or curves slightly toward the lateral margin, resulting in wedge-shaped plates. The dorsal margins of these plates parallel sagittally the stele axis except where they articulate with the insular dorsal plates. The plates change in size and prosopon distally and are nearly equidimensional to almost the end of the stele.

The right series of distal stele plates differs more strongly from its dendrostyloid counterparts. The plates are broader and progress distally, in correlation with alternate position to opposite with respect to the left series, and are pentagonal to quadrate in dorsal and ventral plan. Distally the right plates become progressively

shorter and the degree of opposition between the two series becomes likewise greater. The five most distal plates are essentially opposed dimeres. On paratype VIII there are low, ventral sutural ridges on the distal edge of the otherwise flat plate surface, but they do not extend onto the sides of the plates (see Text-fig. 2).

The sutures between the plates in the distal stele are much wider than those of the dendrostyloid and indicate that fairly free movement was possible. With the widening of the sutures the stele itself also expanded in the plane of extension as is well evidenced by the transversely broader curvature of both right and left series.

The two proximal, insular, dorsal plates are elongate and doubly tapering or faceted. In older individuals the first plate of this insular series may, or may nearly, coalesce with the last dorsal plate of the dendrostyloid by peripheral growth of these plates. Near contact of these two plates is seen in paratype VI. Such coalescence would lengthen the dendrostyloid and may explain the nodes on the sixth and seventh plates of the left series (see Text-fig. 1), which would otherwise be interpreted as dendrostyloid features being continued on the distal stele. The two more distal, insular plates are intercalated at the common point of juncture between two pairs of opposing plates (see Text-fig. 1) and in contrast with the anterior two do not stand up above the general surface level.

In paratype VIII, the stele is transversely broken, exposing the depressed oval lumen, equally contained in right and left series, and in the specimen is well defined by its filling of dark, presumably partially organic remains.

Discussion.—In cross-section the theca of *Syringocrinus sinclairi* is very similar to that of many mitrates, e.g., *Enoploura*, *Mitrocystis*, or *Placocystis*, and is only one of the features that express convergence and parallel evolution of mitrate characteristics in this solute genus. The ventral surface in *Syringocrinus* is concave as in the mitrates and consequently the surface contact with the substrate is reduced. This fact, together with other mitrate-like traits, bespeaks far greater mobility in these forms than in any Eastern Hemisphere solutes. The proximal marginals, to which the attachment muscles of the proximal stele adhere, form a "proximal

girdle", *i.e.*, these two plates comprise the entire proximal margin of the theca. This feature is unique in the Soluta and is uncommon in the Carpoidea; its strength would certainly brace heavy muscular movements of the proximal stele.

Basal or proximal rims serving for reinforcement and stele muscle attachment, present on other members of the order, especially European forms (see Bather, 1913, p. 377, par. 59, 60; Hecker, 1940, p. 24, fig. 15), are not evident on this species.

The lack of extreme dorso-ventral flattening, which is a common preservational condition in most of the Soluta, was largely due to development of relatively thick marginal plates which, as in *Iowacystis*, and the mitrates, provided the theca with a rigid elevated framework. Whereas in *Iowacystis* these bounding plates extend over the ventral surface forming a wide, even border laterally and distally and making up approximately one-half of the total ventral area, here in *Syringocrinus sinclairi* they comprise a smaller total area and extend for varying distances over the ventral surface. Some of these have a irregular ventral configuration. See Text-fig. 3. In this respect *Syringocrinus sinclairi* seems to represent a grade of development intermediate between the irregular dendrocystitids and the regular *Iowacystis*. Regularization has progressed to a stage of more or less fixed positions and constant number of most of the plates, but bilateral symmetry is incomplete, although some bilateral elements seem to be present. Curiously, the thecal regularization here in these Middle Ordovician forms is considerably more advanced than in the Lower Devonian Rutro-clypeidae (Australia and Germany) where the thecal form was fixed (biplanate and circular) but without regularization of plates. In *Iowacystis* the marginals are elevated both dorsally and ventrally to form rather prominent marginal ridges. In *Syringocrinus sinclairi* a partial cross-sectional view of the theca (paratype V) suggests that it was in this respect similar to *Trochocystis bohemicus* Barande (*e.g.*, Jaekel, 1921, p. 119, fig. 108, C), *i.e.*, the ventral surface was gently concave, with the lateral margins being well rounded, and the greatest ventral elevation just inside the lateral marginal.

The stele of *Syringocrinus* is unique among the Carpoidea; while the proximal stele is somewhat conventional in respect to

other solutans, the adjacent dendrostyloid bears little resemblance to any other form. Dendrostyloid evolution consists of the development and extension of the continuous dorsal intercalated plate series of the median stele. This series is plainly seen in *Dendrocystites sedgwicki* and *Heckericystis kuckersiana*. It is possible that this reduced dorsal plate condition, in comparison to *Syringocrinus*, may be an advanced condition. All of the sagittal dorsal plates may be a primitive holdover, entirely lost in the distal stele of almost all solutes and in the median stele also being eliminated in younger forms, viz., *Dendrocystoides* (see Bather, 1913, p. 374, fig. 9). Further evidence that the dendrostyloid is derived from the median stele and is not just a specialized portion of the distal stele, are the small plates on the left flank, intercalated between the first two dorsal plates and the left series. These small intercalates are doubtlessly remnants of ancestral forms where the median stele was polyplated to a greater degree.

The dendrostyloid bears a striking morphological and functional resemblance to the styloid of the mitrates. Both structures are variously flanged or protuberant and both are composed of ankylosed plates, though the dendrostyloid to a lesser degree. It must be assumed that the sutural flanges of *Syringocrinus* acted in an analogous manner to those of the mitrates. To effect this the dendrostyloid (and the distal stele as well) would have to twist counter-clockwise so that the flanges could effectively bite into the substrate. Some of the necessary twisting may have been already present. On some specimens the dorsal series seems canted to the right. The plates may have indeed been dorsal and the flanges then would have been directed into the substrate at ever increasing angles so that the posterior end of the stele was probably turned normal to the substrate. The principal motion of the stele was in the plane of extension, as evidenced by the laterally orientated gliding planes and laterally notched segments in the proximal stele. Thus the distal end of the stele, being normal to the substrate when the animal was in motion, acted as a "caudal-like" sculling organ. This "caudal fin" was enhanced in its efficiency by the rigid dendrostyloid, which, acting in a manner analogous to a circus whip, transmitted with highly increased leverage from the muscular proximal stele the lateral propelling movements.

When the animal was at rest the stele probably was not twisted, or was much less so, and the flat undersurface of the stele rested on the bottom. The rigid dendrostyloid probably bore most of the weight of the stele and, like the theca, presented minimal contact by resting on the ventral ridges of the sutural flanges of the left series and the distal ventral ridges on the right series. These excrescences also would be highly efficient in anchoring the animal in a current. The distal side has, like the dendrostyloid, ventral distal ridges but lacks the ridges on the sutural flanges. Like the distal stele in the Mitrata, it played a minor role in static orientation.

The role of the nodes on the left series is enigmatic. The amount of twisting of the stele was probably insufficient to bring them into contact with the substrate. They may have been stabilizers or counter-balances related to the swimming function of the distal stele.

Types.—Holotype, GSC 17520 (Pl. 16, fig. 1)

An entire specimen except for the brachiole, showing the entire upper surface, much of the theca, and almost all of the stele's lateral surfaces. Stele preservation is good; that of the theca is generally poor and distorted. Some of the sutural flanges of the stele have been inadvertently destroyed in preparation.

Dimensions.—Theca: width, 14 mm. approximately; length, 12 mm. approximately. Stele: length, proximal, 10 mm.; dendrostyloid, 13 mm.; distal, 20 mm. approximately.

Age and locality.—Sherman Falls formation, Middle Trenton group. (Middle Ordovician), Lakefield, Ontario.

Paratype 1, GSC 17521 (Pl. 16, fig. 2)

A nearly complete specimen, lacking almost all of the brachiole and part of the distal stele. This specimen has been essentially the entire basis for the description of the ventral theca. Preservation is fair; thecal sutures and cracks are at times nearly indistinguishable. The proximal stele is depressed and the dendrostyloid seems to be missing part of its lower surface. The base of the brachiole is present and there may be an "anal flap" present on the right posterior marginal.

Dimensions.—Theca: maximum width, 9 mm.; maximum length, 11 mm. Stele: length, proximal, 7-8 mm.; dendrostyloid, 7 mm. approximately; distal (incomplete), 4-5 mm. approximately.

Age and locality.—As below.

Paratype II, GSC 17521a (Pl. 16, fig. 5)

This specimen occurs on the same slab as paratype I. It is a partial specimen showing the incomplete and distorted ventral theca. The proximal stele is somewhat depressed and shows the laterally imbricating meres along the ventral suture of the somewhat depressed proximal stele.

Dimensions.—Theca: length, 10 mm. approximately. Proximal stele: length, 5.5 mm. approximately.

Age and locality.—Upper Trenton group (Middle Ordovician) Chateau Richer, Quebec.

Paratype III, GSC 17522 (Pl. 16, fig. 9)

This specimen, consisting of a deformed and incomplete theca and a twisted proximal stele fragment, occurs on a cylindrical nodule of limestone along with the next two paratypes listed below. It is probably the upper surface because of the bossed prosopon on a few of the plates.

Age and locality.—Middle Trenton group (Middle Ordovician) Lakefield, Ontario.

Paratype IV, GSC 17522a (Pl. 16, fig. 8)

This is an interesting specimen in which the theca is apparently compressed in relation to the complete but mildly distorted proximal stele. There are 12 proximal stele segments and some show the ankylosed lateral sutures and the lateral "notches" accommodating to lateral movement. Preservation has somewhat exaggerated these reentrants.

Age and locality.—Same as paratype III, above.

Dimensions.—Theca: length, 10 mm. approximately. Stele: proximal, 7 mm. approximately.

Paratype V, GSC 17522b (Pl. 16, fig. 7)

This specimen is incomplete and deformed but is one of the most important types in that it possesses an almost entire brachiole. The distal half of the dorsal theca is poorly preserved but provides the evidence that the outer thecal plates were an essentially distinct series. At least two inner (somatic) thecal plates are visible but not in place. The proximal part of the theca is missing, but about 10 badly depressed segments of the proximal stele are discernible. This specimen supplements the holotype in providing a better understanding of the upper thecal prosopon.

Dimensions.—Brachiole: length, 9 mm. approximately; width at base, 2 mm. Theca: width, 8 mm.

Age and locality.—Same as paratypes III and IV, above.

Paratype VI, GSC 17523 (Pl. 16, fig. 4)

The entire dendrostyloid plus small portions of the proximal and distal stele are present. The dorsal plate series which characterizes the dendrostyloid is well shown, even though some of the plates are fractured. A small plate is present between the first two dorsal plates and the left series.

Dimensions.—Dendrostyloid, length, 15 mm. (somewhat deformed).

Age and locality.—Upper Trenton group (Middle Ordovician) Chateau Richer, Quebec.

Paratype VII, GSC 17524 (Pl. 16, fig. 6)

Part of the underside of the distal stele is here preserved, the proximal end of which displays on the inside of the left plates the stele lumen. Sutural ridges of the ventral surface of the right plates are well preserved.

Age and locality.—Upper Trenton group (Middle Ordovician) Chateau Richer, Quebec.

Paratype VIII, GSC 17525 (Pl. 16, fig. 11)

A portion of the distal dendrostyloid and proximal distal stele preserves the sutural flanges and the nodes which here bifurcate near the upper margin of the plate. This specimen shows the hemi-

cylindrical cross-section of the distal stele and the canting of the distal series of plates to the right.

Age and locality.—Middle Trenton group (Middle Ordovician) Lakefield, Ontario.

Note on the occurrence.—Although this is a rare fossil, it is clear from the associations of types that, given the proper environment, *Syringocrinus sinclairi* grew gregariously, and perhaps abundantly, on the shelly facies (shallow benthos) sea floor. Perhaps the thecae and steles were too readily disassociated after death to make preservation common. This is borne out by the amount of nontype material examined by the authors from the same localities that contained small fragments of this new species, especially stele fragments.

Family **IOWACYSTIDAE** Gill and Caster, 1960

According to Gill and Caster (1960) the family Iowacystidae is characterized as:

Soluta with differentiated anal and antianal faces, one having a few symmetrically organized plates, and the other many polygonal plates; theca triangular in outline, compressed. Arm distal but not terminal.

Probably of famillous importance is the added fact that in the type genus there is prosopon on the marginals and upper somatic plates which seems to mark the course of a tissue system of unknown function.

Gill and Caster in their 1960 classification of the Soluta show the Iowacystidae as an aberrant lineage of the order. It is furthest in specialized traits from the dendrocystitid stock of any solute, even further than the Rutroclypeidae of the Devonian. Partially indicative of this specialized condition is the reduction in number of thecal plates, trigonal fixed outline, and the proximal dorsal migration of the arm attachment. This monotypic family is the latest American Ordovician (Richmondian) expression of the Soluta. The Ashgillian *Dendrocystoides* of the Scottish Girvan district is about the same age.

Genus **IOWACYSTIS** Thomas and Ladd, 1926

Diagnosis.—Triangular theca with well-defined symmetrical marginal plates bearing deeply impressed grooves and elevated

nodes defining a unique, repeated, arcuate tissue system. Ventral somatic plates regularized; dorsal surface with many irregular plates having radially arranged nodes and ridges. Anterior, dorsal somatic plates specialized: one (G plate) with an elevated pore, the other two receive the elevated but recessed arm. Anal structure a pair of opposing erectile plates partly surrounded by a number of smaller plates.

Proximal stele tetramerous with smooth internal articulating surfaces; distal stele unevenly dimerous with ventrally located, isolated, raised, intercalated plates.

Type species.—*Iowacystis sagittaria* Thomas and Ladd, 1926; Maquoketa shale, Fort Atkinson limestone member (Middle Maquoketa), Upper Ordovician (Richmond).

Discussion.—This genus was established by Thomas and Ladd (1926) on the basis of four specimens and several fragments collected from the Fort Atkinson limestone (Upper Ordovician) near Fort Atkinson, Iowa. The authors identified it as a "heterostelean cystid", *i.e.*, carpodid, but, not recognizing its dendrocystitid affinities, thought of it lying close to the "anomalocystitids," (Mitrata: Mitrocystidae or Lagnocystidae). Troubled, however, by the peculiarities of *Iowacystis*, Thomas and Ladd did speculate (1926, p. 6) that the "genus may eventually be relegated to a new family."

Bather (1926, pp. 233-234) presented a summary of Thomas and Ladd's paper, rejected their classification, and spotting its true affinities said:

It is, however, plain that it is a *Dendrocystis* at about the same level of evolution as *D. scotica* though on different lines.

Bather (1928, pp. 5-7) continued to maintain that this genus was synonymous with "*Dendrocystis*", suggesting its ancestry lay in the European "*Dendrocystis*" *barrandei* out of which the American species had independently evolved.

Dehm (1934, p. 21) began the process of resurrecting the genus *Iowacystis*. He considered it a subgenus of *Dendrocystites*, noting that this is the original spelling of the generic name rather than Bather's "*Dendrocystis*." (However, Dehm then proceeded to introduce the variant "*sagitarus*" for the trivial name.)

Bassler (1938, pp. 9, 85) and Bassler and Moodey (1943, pp. 4,

149) followed Bather in considering *Iowacystis* as a synonym of *Dendrocystites*, recognizing no subgenera.

Gill and Caster (1960, pp. 20-22) redefined *Iowacystis*, establishing it once more as a separate genus, the basis of their new family, the Iowacystidae.

The original study by Thomas and Ladd gave the broad attributes of the genus. However, further study and preparation of the type material yields new data which are incorporated both in the foregoing generic diagnosis and the ensuing species diagnosis. Details of the reexamination appear under the species analysis below.

Iowacystis sagittaria Thomas and Ladd, 1926, emend. Pl. 17, figs. 1-8;
Pl. 18, Figs. 1-7; Text-figs. 5-10

1926. *Iowacystis sagittaria* Thomas and Ladd, Additional Cystoids and Crinoids from the Maquoketa Shale of Iowa, Univ. Iowa Studies Nat. Hist., Papers on Geology, vol. II, No. 8, pp. 5-10, p. 1, 2, 4, 5.

1926. "*Dendrocystis*" *sagittaria* (Thomas and Ladd), Bather, Review: Thomas and Ladd, Additional Cystoids and Crinoids from the Maquoketa Shale of Iowa, Geol. Zentralblatt, Bd. 34, No. 5, pp. 233-234.

1928. "*Dendrocystis*" *sagittaria* (Thomas and Ladd), Bather, *Dendrocystis* in North America, Canada Dept. Mines, Geol. Sur., Bull. 49, (Geol. Ser. 48, Contrib. Canadian Paleont.) pp. 5-7.

1933. "*Iowacystis*" [*sagittaria*] Thomas and Ladd, Dehm, Cystoideen aus dem rheinischen, Unterdevon, Neues Jahrb. Min., Beil., Bd. 69, Abt. B, p. 65.

1934. *Dendrocystites (Iowacystis) sagittarius* Thomas and Ladd, Dehm, Untersuchungen an Cystoideen des rheinischen Unterdevons, S. -B, Akad. Wiss. Munchen, Math.-naturw., Abt. 1934, pp. 20, 21, 36-41, fig. 5d, e, p. 37.

1938. *Dendrocystites sagittaria* (Thomas and Ladd), Bassler, Pelmatozoa Palaeozoica, Fossilium Catalogus, 1; Animalia, pp. 9, 85.

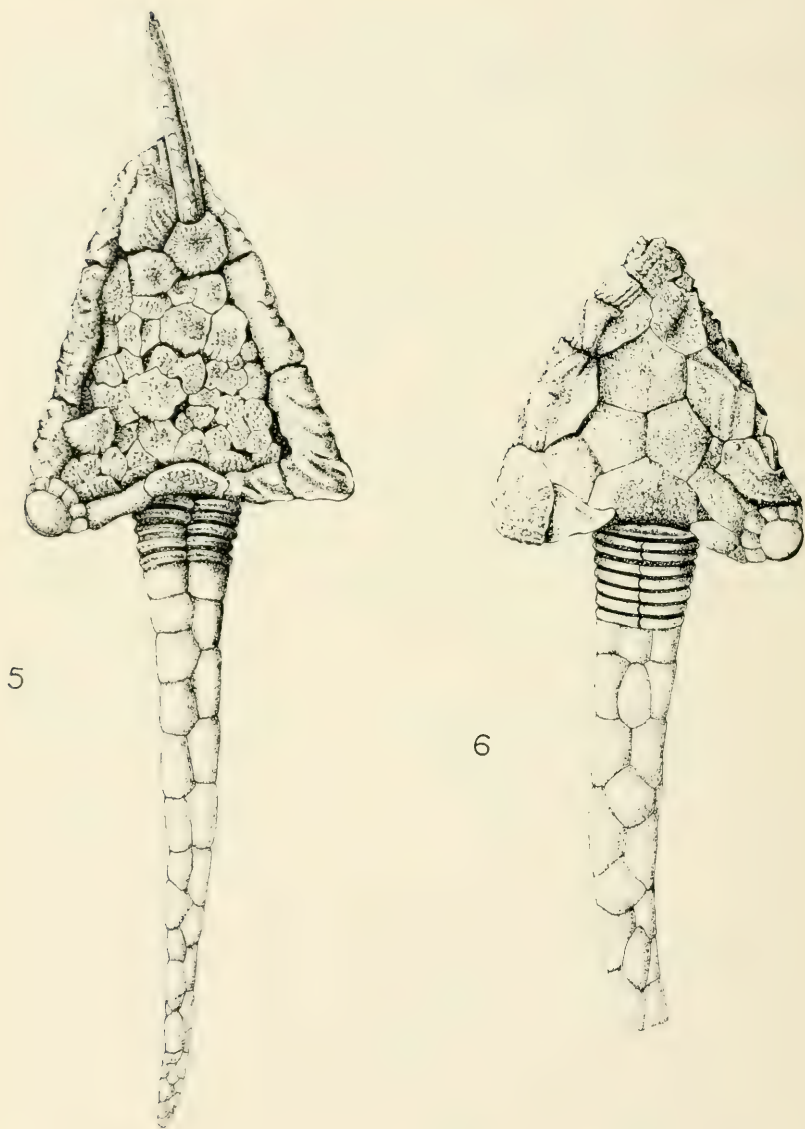
1941. "*Dendrocystis*" *sagittaria* (Thomas and Ladd), Chauvel, Recherches sur les Cystoïdes et les Carpoïdes Américains, Soc. Géol. et Minéral. de Bretagne, Mémo., T. 5, pp. 7, 241.

1943. *Dendrocystites "sagittarius"* (Thomas and Ladd), Regnéll, Non-Crinoid Pelmatozoa from the Paleozoic of Sweden, Lunds Geol.-Min. Inst., Medd., Bd. 108, pp. 41, 195.

1960. *Iowacystis sagittaria* Thomas and Ladd, Gill, and Caster, Carpoïd Echinoderms from the Silurian and Devonian of Australia, Bull. Amer. Paleont., vol. 41, No. 185, pp. 20-22, 24, 29.

Diagnosis.—Depressed, triangular in outline. Theca composed of ten marginals, two marginal basals, six ventral somatic and approximately 40 dorsal somatic plates;⁹ Lateral extensions of mar-

⁹Both *Syringocrinus* and *Iowacystis* appear to retain flexible, loosely articulated dorsal somatic areas, similar to the overall integument of the non-American solutes. This strongly suggests that some degree of thecal flexibility was necessary for the basic physiologic economy in the order. It has been suggested by other writers that these motile forms may have depended upon pumping action of the gut, perhaps in connection with microphage habits or a mode of ingestion supplemental to the ambulacral food gathering.



Text-figs. 5, 6. Two views of *Iowacystis sagittaria*, Thomas and Ladd, 1926. 5. A partial reconstruction of the dorsal surface. Drawing is based on the holotype (SUI 3525). Length and configuration of the arm is inferred. 6. A partial reconstruction of the ventral surface. The figure is based on three paratypes, (SUI 3526, 3528, 3529, A, B, C). Note the prosopon, ventral portions of the arcuate grooves on the marginal plates, and the high degree of symmetry.

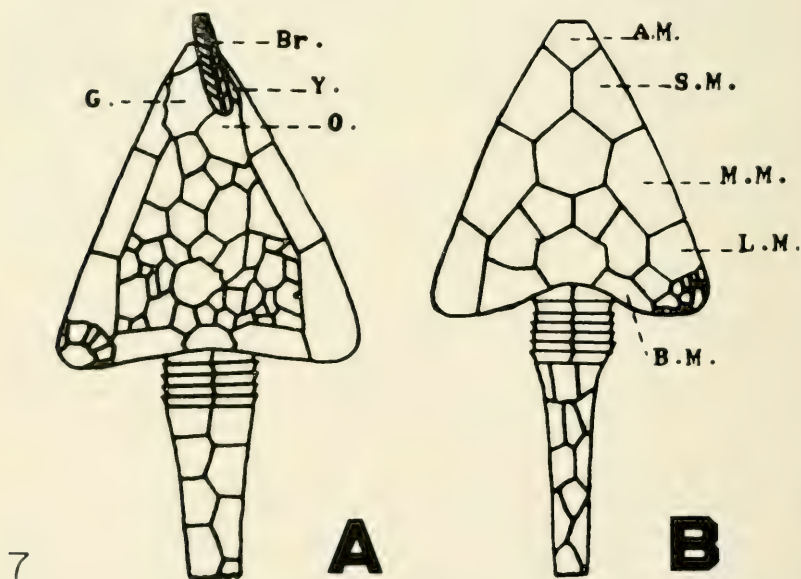
ginals comprise more than half of ventral surface, marginal extent over dorsal surface limited to narrow peripheral band; theca bi-convex across the mid-line; anus covered by two opposed subcircular plates which are partly surrounded by a circle of five or six quadrate plates on each face. There are seven segments in the proximal stele, five ventral intercalated plates in proximal part of the distal stele; its more distal part is irregularly multiplied.

Thomas and Ladd (1926, pp. 7, 8) did not consider the "basal" median plates of the two thecal faces to be marginals but rather integral parts of their respective thecal faces (see Text-fig. 7). While this is probably the proper way to denominate them, these plates were marginal in function, providing part of the rigid peripheral framework. The prominent ridge on the lower median plate no doubt contributed to the marginal rigidity and certainly is in keeping with the general character of the other bounding plates. Much of the musculature of the proximal stele was in all probability attached to the prominence of the lower median plate. Although the upper median plate is also marginal in function, it bears the prosopon of the upper thecal plates and lacks the strong ridge. This plate probably served as a counter-brace to the stronger, lower median (see Text-fig. 5). Unlike the condition in the *Mitrata*, where plate standardization had proceeded much further, the "marginals" in the *Soluta* are best thought of as simply thecal plates which have become thickened and ankylosed to form a rigid perimeter. No homology can be drawn between these bordering solute plates and the marginals or other border plates of other car-poids.

The three lateral marginals are elongated; at the distal apex is the shorter, apical marginal. Adjacent to it, on the upper surface, are three specialized plates called the "G," the "Y" and the "O" by Thomas and Ladd (see Text-figs. 7, 8). The "G" plate, on the left side, is elevated into a tubular cone with a clearly defined pore at the apex. It was originally postulated to be a gonopore. Tiny, perforated pustules on the flanks of the cone were also observed (*ibid.* 1926, p. 10). Bather (1928, p. 6) suggested that this plate might be a combined madreporite and gonopore. Close examination, however, has shown that the "pustules" are in fact small grains of the

dolomite matrix and the surface texture of the elevated portion of the plate does not differ from adjacent plates and no basis for the madreporite sieve plate exists. Whether or not the pore was genital is open to speculation; it may still have been a water intake pore, *i.e.*, hydropore.

To the right of the "G" plate is situated the arm which seems to issue from the elevated "O" plate (see Text-figs. 5, 6), and it is beneath this plate where the "mouth" is doubtlessly located. Juxtaposed to the right of the "G" plate is the "Y" plate; both of these form a groove in which the basal lower half of the arm rests.



Text-fig. 7. Plate pattern of *Iowacystis sagittaria* Thomas and Ladd. Based on specimen Nos. SUI 3526, SUI 3528, from Thomas and Ladd, 1926. A. Dorsal view: *Br.*, brachiole; *G.*, "gonopore" plate with an elevated pore; *O.*, oral plate, from the distal margin of which emerges the arm; *Y.*, small grooved plate that partly supports the arm. B. Ventral view: *A.M.*, apical marginal; *S.M.*, superior marginal; *M.M.*, median marginal; *L.M.*, lower marginal; *B.M.*, basal marginal. Compare with the more detailed representation of the plates in Text-figs. 5, 6, based on the same material.

The tetraserial subvective arm comprises a series of large, alternate plates partly enclosing a smaller, dorsal series which is also probably paired. The dorsal plates were erectile coverplates, roofing the food-groove. Virtually all knowledge of this structure in *Iowacystis* comes from specimen SUI 3528 (Pl. 17, fig. 10) where only part of the proximal portion is preserved. Its total length is conjectural, but judging from its width at the base and extrapolating, its extension from the "O" plate to its terminus amounted to approximately one-half of the length of the theca, as shown in Text-fig. 5.

In the left proximal apex there is a break in the marginals; intercalated there is a group of five or six small subrectangular plates radiating into the theca in a double series (one series on each of the two thecal faces) from a pair of apical opercular plates. This anal apparatus is similar in position to other Ordovician solutens, *i.e.*, on one of the proximal apices of the theca. Fecal extrusion is believed to have been between the double apical plates, (see Text-fig. 9). In none of the specimens does this anal area seem to be complete and is usually fragmentary or missing because the plates were clearly loosely articulated. Bather (1913, p. 370, par. 74) imagined the waste outflow was effected by the sphincter-controlled opening of the radiating plates away from the single "sugar loaf" plate in the genus *Dendrocystites*. Possibly the "sugar loaf" plate needs to be reexamined for other organization.

The under thecal surface was pauciplated (about six plates) and was presumed to have been concave by Thomas and Ladd (1926, p. 6). This certainly would be expected, for it is the case in virtually all carpoids. However, the ventral faces of the marginals flare convexly and this is accentuated by the more or less well-defined groove between the inside edges of the plates and the marginal ridge. The somatic plates, however, show every sign of having been tightly sutured but are usually depressed below the marginal frame and not in original sutural contact with the marginals.

There still persists, moreover, a strong indication in some specimens of original ventral convexity. On paratype No. 3528 (Pl. 18, fig. 2), the distal ventral somatic plate is still distinctly convex; and on paratype No. 3527 (Pl. 17, fig. 4), there remains more than a suggestion of this convexity over the mid-ventral face. The gen-

eral characteristics of the ventral somatic plates are most adequately described by Thomas and Ladd (1926, pp. 7, 8); these plates are covered by scattered, low, round, smooth pustules (see Text-fig. 6).

The upper surface is covered by approximately 40 somatic plates, as Thomas and Ladd (1926, p. 8) showed, and the three specialized plates. All of these upper somatic plates are covered by prosopon unique to the Carpoidea.

In addition to bearing a generally granular aspect, the adjacent portions of the "G" and "O" plates have elevated, roughly parallel ridges (approximately six in number) which are continuous from one plate to the other, giving an appearance somewhat similar to that of an eroded cystid conjunct pore-rhomb (see Pl. 17, fig. 1). On the "O" plate similar ridges and furrows are normal to the sides. The radiate structure appears to be part of a general radial costation of most of the dorsal somatic plates. This radiate prosopon feature has been seen best on the holotype; the other specimens are somewhat eroded.

This prosopon on the dorsal somatic plates consists of nodes or bosses which are irregularly rounded in plan and cusped in profile. These nodes usually coalesce to form irregularly aligned ridges of varying width and height. In the center of each plate there is (usually) a central cusp or boss encircled by seven or so equally spaced bosses of lesser height, and radiating away from this circlet are the numerous, slightly meandering ridges. In some instances the ridges give way to isolated cusps located in the same linear trend. Some somatic plates, especially those near the marginals, are not embossed with such a clear-cut pattern. The interr ridge depressions or grooves are generally wider than the ridges which coincide with those on adjacent plates and may be the imprint of an enigmatic, intricate canal system, such as has never been reported.

Other genera of the Soluta have elevated prosopon on the somatic plates consisting of single, raised bosses or low spines, viz., *Rutroclypeus* Withers (e.g., Gill and Caster, 1960, pl. 7) bears hollow spines over the entire surface or *Heckericystis* (e.g., Hecker, 1940, p. 24, figs. 14, 15) bear mammaliform bosses. *Dendrocystites sedgwicki* bears elevated circular bosses on the plates of the dorsal proximal region and extending to each corner of these polygonal

plates there is a well-defined crease or fold (*e.g.*, Barrande, 1887, pl. 26, figs. 1, 6-9, 18, 19). The prosopon configuration of this species is somewhat reminiscent of the upper somatic plates of *Iowacystis* but appears not to be homologous. Bather (1913, p. 375, par. 49) interpreted the plate folding in *Dendrocystites sedgwicki* as an economic device. Bather (1928, p. 6) thought that the dorsal plates in *Iowacystis* were similarly axially folded and ridged, and to be correlated with this was the enlargement of the thecal plates and the concomitant reduction of the total plate number during phylogenetic development.

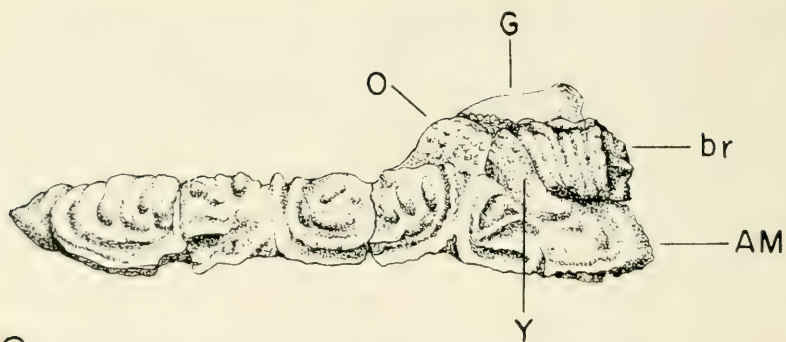
The marginal prosopon of *Iowacystis* is unique. Thomas and Ladd (1926, p. 7) described it:

The peripheral faces of the marginals are conspicuously decorated (*sic*) by an intricate system of ridges and grooves. The median marginals, and to a certain extent those above and below them, are constricted at their mid-length. In the broad depression thus formed lies a narrow, transverse ridge which is a slender continuation of the smoother and less decorated posterior surface of the plate.

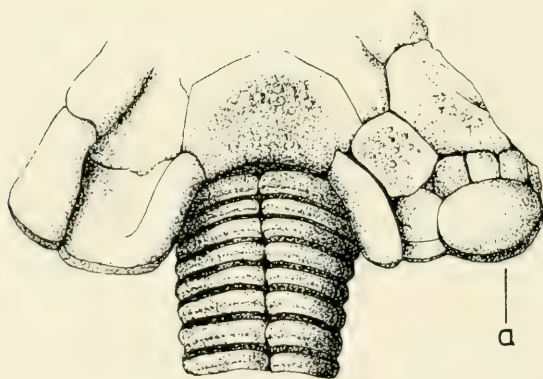
They go on to say (*ibid.*, p. 10):

The elaborate system of grooves and ridges on the marginals and their evident continuity from plate to plate along the periphery of the theca suggest that they may have had a part to play in the economy other than decoration.

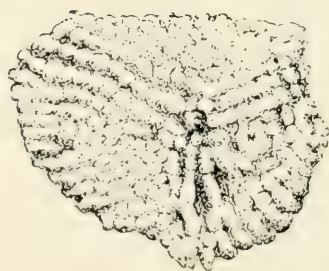
The lateral marginals (three on each side) are each divided by a prominent dorsal-ventral ridge which bifurcates in the two more distal pair and continues as a curved ridge along the ventral periphery (see Pl. 17, fig. 7, 8). At the extremity of each plate the ridge is indented about twice its width on the ventral face of the theca. At the anterior and posterior edges the plates obtain their greatest thickness; the mid-portion is thinner, giving the plates a constricted aspect. The ridge(s) from the adjacent plate(s) coincide ventrally at the sutures to produce, in overall aspect, a ridge that is smoothly arcuate from the mid-area of one marginal to the mid-area of the adjacent marginal. The dorsal-ventral ridge does not split on the left proximal lateral marginal and simply is confluent with the arcuate configuration of the adjacent distal plate. The proximal portion of this plate is devoid of prosopon and somewhat truncated, due to the intercalation of the plated anal system. On the right side the normal bifurcation of the ridges is ob-



8



9



10

Text-figures 8-10, explanation page 151.

served. The ridge extends proximally in the normal arcuate fashion from the medial dorsal-ventral ridge to the proximal apex and continues on to the basal marginal where it terminates on the dorsal surface of the plate close to the upper median marginal. The ridge does not extend on to the ventral surface of this basal marginal but maintains itself along the ventro-lateral edge of the plate.

Orad to these arcuate ridges is a corresponding, rounded furrow of half again the width of the ridges. Dorsal to this furrow is a complex system of ridges and elongated nodes of varied size and shape and in this system the inter-ridge furrows tend to correspond closely with the raised elements (see Text-fig. 8), and in section are like the arcuate grooves ventral to them (rounded), but some of the more dorsally located grooves are flat bottomed.

The trend of these nodes and ridges is uniform: those next to the dorsal-ventral ridge tend to lie parallel to it while those near the edges of the plates are essentially horizontal (*i.e.*, are more or less parallel to the arcuate ridge) and always line up with a node on the adjacent plate. Some of the longer nodes actually bend from the dorsal-ventral position to a near horizontal trend near the plate edge. There generally seems to be at least two or three grooves going from one plate to another as delineated by the aligned nodes. In specimens where the marginals are not eroded the nodes are all of the same general height and do not vary greatly in thickness.

On the apical marginal Thomas and Ladd (1926, p. 7) describe the prosopon as follows:

... a smooth linguiform elevated band forms the extreme apical part and extends from the posterior surface, of which it is a continuation, down to the apical edge of plate G: a distinct groove flanks each side of this apical band, for the reception of which it is slightly undercut.

Text-figs. 8-10. Three views showing various aspects of *Iowacystis sagittaria* Thomas and Ladd. 8. Drawing of the lateral thecal profile of paratype (SUI 3526) showing the arcuate grooves which extend from the arm to the proximal edge (and along the basal margin, terminating near the stele). Note the elevation of the dorsal anterior plates. For explanation of lettering see Text-fig. 7. X 3. 9. An oblique view of the indented proximal ventral margin. Figure is based on paratypes SUI 3526, 3528. Note the greater number of proximal stele segments visible here as compared to the dorsal view in Text-fig. 5. a = anal apparatus. Approx. X 6. 10. Drawing of a dorsal somatic plate. Note the pustular nature of the radiating ridges. Approx. X 10.

This ridge or band is the most distal structure of the theca and marks the closest separation of the two arcuate groove systems (see Pl. 17, fig. 6). These grooves on either side reach their furthest extent ventroapically, then recumbently recurve orally (see Text-fig. 8). On the right side the recurved groove terminates after crossing the suture between plates "G" and "Y", just below the aboral base of the brachiole where plates "G", "Y" and the apical marginal meet. On the left side the groove terminates a short distance across the zigzag suture on the "G" plate. This zigzag suture between the "G" plate and the apical and anterior marginal plates is unique in its serrated appearance (see Pl. 17, fig. 8).

The open continuity of the arcuate grooves and ridges, the consistent orientation of the more dorsally situated nodes and grooves on the marginals, and the anastomosing-radiate network on the dorsal somatic plates argues for more than just excess "ornament" in a terminal evolutionary stock. Perhaps this system played some role in the animal's economy. It is possible that this network contained tissue of unusual thickness (*i.e.*, for the external surface of echinoderms) and may have functioned as a respiratory organ and as a sensory system as well.

The tetramerous proximal stele in *Iowacystis* (Text-figs. 5, 6) has on its oral and aboral sides alternating, slightly imbricate meres similar to those in *Syringocrinus sinclairi*. The curved internal articulating surfaces are well developed and considerable flexibility was possible. The external portion of each mere has a broad, low ridge along both proximal and distal margins, and probably served for muscle attachment. The lateral sutures, nowhere seen intact, are, on examination of their joining surfaces, similar to those of *Syringocrinus sinclairi*. The proximal stele is recessed within the basal marginals by at least two segments and was presumably attached by muscles to their inner surfaces. Due to the basal reentrant on the aboral side seven segments are visible, as opposed to five on the oral side.

The proximal stele in life was probably inflated, as evidenced by the large stele aperture of the theca and especially as delineated by the strong outbending of the lower median marginal. It can be inferred that the stele lumen was large, and sufficient musculature was present to effect fairly strong wriggling for locomotion.

The tapering distal stele consists of offset, general pentagonal dimeres. Inside them is a narrow lumen which is circular in section. In cross-section the distal stele is semicircular, being flattened on the *upper* surface while the lower surface is rounded. This is a reverse of the stele condition seen in *Syringocrinus*, above. Isolated, irregular, intercalated plates are present on the lower surface and are slightly raised (see Text-fig. 6, Pl. 17, figs. 5, 7). No homology is likely between these intercalated plates and those of *Syringocrinus* since they occur on the opposite side of the stele. The convex surface offers a minimum of contact with the sea bottom, and the principal points of contact are the intercalated mid-ventral plates.

Fragments of the apical portion of the distal stele show that the regular plate pattern gives way to increased intercalations by smaller, polygonal plates, creating a polyplated condition (see Text-fig. 5, Pl. 17, fig. 6). The more distal section is less plano-convex, grading into a depressed oval zone, and finally into terminal tereteness.

On the holotype a mass of continuous plates resembles a swollen terminal structure. However, this is due to disarticulation and the irregular concentration of the distal stele plates (Pl. 17, fig. 1). Thomas and Ladd (1926, p. 9) were unsure whether these plates belonged to the stele.

The median stele is absent in *Iowacystis* as it appears from Bather's Studies to have been in *Dendrocystoides* Jaekel of nearly the same age, *i.e.*, Ashgillian of Scotland. This elimination of the median stele seems consistent with the progressive reduction of this zone as seen in older forms.

Measurements of the types, *Iowacystis sagittaria*, from Thomas and Ladd, 1926, p. 10.

	SUI 3525	SUI 3526	SUI 3527	SUI 3528
Total length of theca	22.0 mm.	22.0 mm.	13.0 mm.	22.7 mm.
Width at base	21.0 mm.	20.0 mm.	11.5 mm.	20.5 mm.
Length of median marginal	7.6 mm.	8.2 mm.	5.0 mm.	7.9 mm.
Length of plate O	4.5 mm.	4.5 mm.	—	—
Length of plate G	6.0 mm.	6.0 mm.	—	5.5 mm.
Stem, oral side of proximal series	6.0 mm.	7.0 mm.	—	6.6 mm.
Stem, posterior side of proximal series	—	8.1 mm.	—	8.4 mm.

"Dendrocystitid" Ubaghs, 1963

Pl. 16, fig. 10

Ubaghs, 1963. *Cothurnicystis* Bather, *Phyllocystis* Thoral and an undetermined member of the order Soluta (Echinodermata, Carpoidea) in the Uppermost Cambrian of Nevada, Jour. Paleont., vol. 37, No. 6, pp. 1141-1142.

A single specimen which consists of an imperfectly preserved stele has been described by Dr. Georges Ubaghs (1963). He has assigned no nomenclature to the specimen, and it is his opinion that no valid taxobasis exists in the imperfect material. Dr. Ubaghs generously lent the authors the portion of his manuscript dealing with this specimen prior to publication; the authors examined the specimen through the courtesy of Dr. Porter M. Kier of the U.S. National Museum.

The proximal stele is tetramerous, tapering, without prosopon, and consists of approximately 13 segments (see below). It is truncated anteriorly by a narrow calcite vein, across which may be further stele and some thecal material but is poorly preserved. The specimen presents its lateral side and running the length of the proximal stele is a low, continuous ridge corresponding to the lateral sutures which, as in *Syringocrinus*, are ankylosed. The meres seem to have low ridges on the proximal and distal margins of the exposed portion of the plate, as in *Iowacystis*.

Details of the median stele are obscure, if indeed it was differentiated. Ubaghs (*ibid.*) stated: "The existence of a third or median region is possibly indicated by a rapid narrowing of the organ between the proximal and distal region."

The distal stele posterior to this abrupt narrowing tapers gradually to the apex. The stele distal to the proximal stele seems to consist of seven segments. The lateral face, which is uppermost on the specimen, is, for the most part, gone, resulting in a flat surface. On the left side of the mid-area there are (dorsal-ventral) sutures (wetting the plates and low oblique being necessary to bring them out) which resemble those of *Dendrocystites rossicus* Jaekel¹⁰

The plates in the distal stele shorten distally and the proximal portion seems to be more rigid (*vide* Ubaghs, 1963).

Discussion.—Ubaghs (*ibid.*, 1963) in his analysis considered

¹⁰Ubaghs (personal communication), in his study of *Dendrocystites vidali*, has reached the same conclusion—"... the distal portion of the stele ("Dendrocystitid") is similar to that of *Dendrocystites rossicus*."

the specimen orientated with either dorsal or ventral face uppermost and that the proximal stele had retained to some degree its depressed oval cross-section. Because there seems to be little evidence of twisting and, in light of the fact that the dorsal-ventral sutures are found on the side of the specimen, a different orientation seems to be the case. It is likely the proximal stele was in life more circular in section, *e.g.*, like *Syringocrinus*. The nature of the dorsal and ventral proximal stele sutures is unknown, but it is likely, as in other tetramerous forms, that the meres alternately overlapped one another along these sutures.

Ubaghs (1963, p. 1141) noted that at least 20 segments are present in this zone and it is possible that he was able to discern further segments across the aforementioned calcite vein. If this be true, and the fact that *Dendrocystites vidali* Thoral (Lower Ordovician) also had a large number of proximal stele segments, 25 or more, credence is given to an earlier statement that within the Soluta there was a tendency for a general reduction of proximal stele segments in the group's phylogeny. This statement also seems to hold for the median stele (*Syringocrinus* excepted) but unfortunately, due to the poor preservation of the specimen, it can not be justly tested here.

The distal stele of the specimen was depressed in life, probably not unlike the previous North American genera.

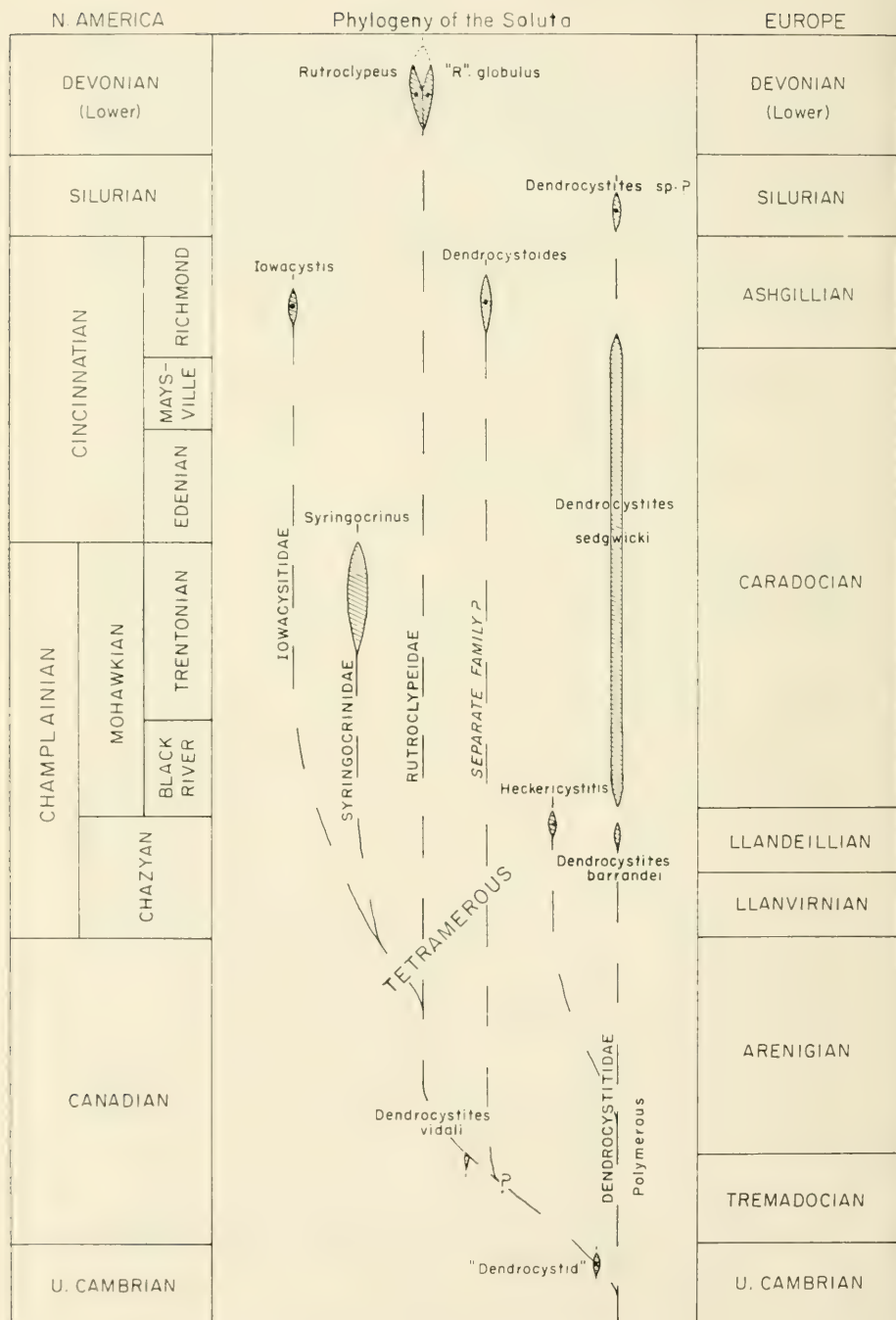
The ridge seen on the upper portion in this zone of the specimen is most likely due to deformation; however, in the "median stele" zone it appears that the original surface is preserved and the sharp curvature may well represent the lateral convexity.

It would assuredly not be stretching credulity to assign this important earliest record of the Soluta to the Dendrocystitidae, even though Ubaghs is wise in not attempting the generic analysis which further material will almost certainly require.

The specimen is from the Upper Cambrian and is the earliest known solute. It was taken from the Whipple Cave formation near Lund, Nevada, in Sawmill Canyon.

PHYLOGENETIC CONSIDERATIONS

Ubaghs (1963) described from the Upper Cambrian of Nevada



Text-fig. 11. Phylogeny of the Soluta.

a dendrocystitid-like stele in which the proximal zone is imbricate, tetramerous, and long (perhaps up to 20 segments). Although Ubaghs has not deemed this most ancient known solute adequate for taxonomy, the specimen strikes him as resembling *Dendrocystites vidali* Thoral (1935) from the Upper Tremadocian or Lower Arenigian (Upper Cambrian or Lower Ordovician) of the Montagne Noire of southern France, the previously oldest record of the order.

Both of these are earlier in the record than the first occurrence of a form with a polymerous proximal stele, *i.e.*, *Dendrocystites barrandei* Bather (1913), Middle Llandeilian, d2, = Chazyan: Lower Middle Ordovician.

It is generally believed that the proximal stele was originally derived from the proximal portion of the polyplacated theca. Bather (1913, pp. 382-383, par. 84-88) in discussing *Dendrocystites* speculated that the solute stele was a relic stem which had developed by progressive lengthening and regularization of the basal theca. Since all known carpoids were eleutherozoic, as were the earliest echinoderms recorded [Lower Cambrian, Helicoplacoidea, Durham and Caster, 1963, and most Eocrinoidea, (Caster, 1963)], this speculation is now strictly unsubstantiated and even questionable. Certainly in all known solutes (all carpoids, for that matter) the theca and stele are sharply differentiated and nowhere gradational. In all forms the proximal stele is a flexible zone, apparently well provided with muscles in life, and apparently locomotor in function. It is always inserted into the proximal theca and attached thereto presumably by muscles.

So far the record testifies to three evolutionary solutions to a flexible proximal stele requirement. a) The essentially integumentary solution seen in *Dendrocystites barrandei* and *Dendrocystites sedgwicki* where many small discrete platelets in several circlets, also discrete, alternate with single rings of somewhat larger discrete plates. Apparently most of the proximal stele area in these was integumentary and the calcifications pretty much incidental, their localization being determined by concentric rugae of the integument (or whole body wall). b) The *Heckericystis* solution in which imbricate calcified rings constitute the proximal zone. The particle constitution of these rings is not known, but four-part con-

struction is likely. c) The "anomalcystid" solution of tetrameres which are imbricate axially and to a greater or less degree sagittally, usually more so on the lower side than the upper.

If the carpoid heterostele derives from a stem, column or pelmatozoic holdfast, that condition is unknown so far in the geologic record, however plausible it seemed to Bather and his school.

Just as plausible is the idea that the heterostele, as known in even much earlier times, a "tail," or "tige" as it is in French, is no more to be correlated with the pelmatozoic stem than is a chordate tail with a hawser. Posterior appendicular organs can obviously have diverse origins.

Although the "flat-fish" habitus of ancient echinoderms is incompletely understood, it is manifest that when evolution took this course, whether in eocrinoids, carpoids, or cystids, and whether out of a pelmatozoic and radial situation, the polyplated "eleutherozoic" generalized eocrinoid (*Eocystites*) or the bilateral, precarpoids, the proximal flexibility was acquired.

The eocrinoid "tail" (*i.e.*, in *Eocystites*, personal communication, J. Pope and K. E. Caster, 1963), was irregularly polyplated and seemingly reasonably flexible, especially in the region where it graded into the thecal portion. Apparently the more distal portion was tightly fused. In the much flattened *Rhipidocystis* [Hecker's carpoid "order" *Digitata*, which *fide* Pope and Caster (personal communication, 1963) belongs in the Eocrinoidea], the tail is reduced to a short, tapering, annulated rudiment. (Whether the annuli are polymerous or not is unknown.) In the archaic order *Cincta* of the carpoids (*Trochocystis*, *Gyrocytis*, *Decacystis*) the "tail" is polyplated and not differentiated into flexible and inflexible zones, although it appears that the more distal part is more irregularly plated and the proximal portion gradually takes on a biserial scheme, with sagittal intercalated plates assuming an increasingly important role in the expanded ad-thecal zone.

If one continues on the assumption that the stele is in fact a reduced structure derived by constriction of the posterior portion of the theca, a question of growth arises: *i.e.*, where is the proximal plane? In this and all other works it is taken to be at the juncture of the theca and proximal stele. It is likely that primary growth

does occur here in the pelmatozoan sense. There is also some evidence to support primary growth at the juncture of the proximal and median stele. The indistinct and seemingly incomplete distal ("annulus") segment of the proximal stele might be in the process of formation. However, if there be one or two planes, or none at all, the various parts growing by intercalation and concentric growth of plates. The term "proximal plane" is not in the strict sense synonymous with pelmatozoan usage. In the Pelmatozoa it can be embryologically demonstrated that here is the confluence of two separate parts of the organism, the stem and the theca. We, of course, have no knowledge of carpodid embryology but a non-pelmatozoan mode of development for these organisms is not unlikely.

The sagittal intercalates apparently characterize all carpoids and play a prominent role in the evolution of the peculiar traits of the heterostele, be they the tetramere condition of so many proximal steles, sagittally intercalated as the ventral styloid, and perhaps even contributes elements to the stylocone process of the mesostele zone. More immediately, they are found on the dorsal surface of the median stele zone in *Syringocrinus* to form part of what is here termed the dendrostyloid.

In individual carpodid steles there is recurrent indication of a distal to proximal ontogenetic rehearsal of stele history with respect to the mere organization. This may be a demonstration of the principle elaborated by Robert Tracy Jackson and commonly known as "Jackson's Law." Those carpoids which retained in the adthecal area of the stele sagittal plates alternating with the "laterals," i.e., *dimeres*, may retain the clue to the otherwise perplexing origin of the four part (tetramerous) organization of so many carpodid proximal steles. Bather (1913, p. 395, par. 148) conceived of fission of dimeres in the adthecal area leading to this condition. It seems more likely that the common echinoderm evolutionary tendency here prevailed, whereby initially alternating plates became opposite, thus forming circlets, and by fusing became annuli (columnals in crinoid stems, circlets in crinoid heads).

In the order Cornuta (*Cothurnocystis*) the mesostele stylocone may be an annulus comprised of tightly ankylosed dimeres and two opposite sagittals. This must await sectioning of a stylocone for

possible confirmation. Possible insight into this organ is the distal segment of the *Syringocrinus* proximal stele which is a four-part "annulus." In the order Mitrata the ventrally intercalated styloid process, which (*fide* Caster) is polymerous and likewise tightly ankylosed, has posed some problem: Does it belong to the proximal stele and hence represents a ventral sagittal insertion of the four-part organization? It appears in the light of seeming Jacksonian rehearsal of carpoid steles that this ventral intercalation may well be a specialization of the mesosteles sagittals, the dorsal counterparts probably having in most lineages been suppressed. In *Syringocrinus* a dorsal homeomorphic development of an ankylosed styloid sagittal series has been noted above. In *Iowacystis* the generalized sagittal intercalates persist in their archaic, alternate state. By expansion and by becoming opposite in respect to the adjacent dimeres in the proximal stele the sagittals would account for a right and a left plate in each "ring," one ventral and one dorsal, and the corresponding left and right plates would be modified dimeres. This entails right and left migration of the sagittal intercalates out of the sagittal plane, so that in the "anomalocystid" imbricate proximal stele the often imbricate juncture of the intercalate and its opposite dimere comes to lie in that plane. In this connection, it has been noted that in *Syringocrinus* the dorsal sagittals of the dendrostyloid show a tendency distally to migrate from the axial plane toward the *right*. Hence there is evidence of migratory trends in the stele plates. It now appears that this modification of the proximal stele was independently achieved several times in carpoid history, but probably out of a common heritage of dimeres and sagittal intercalates.

Within the Dendrocystitidae the polymerous forms known by *Dendrocystites barrandei* and *Dendrocystites sedgwicki* probably represent a terminal line of evolution rather than a relic* of the most primitive carpoid "tail" or stele type, irrespective of which philosophy of development seems the more valid; unless, that is, the polymerous condition be considered an aberrant proliferation of plates in the proximal stele region, which is also plausible. An

*This surmise was substantiated by a restudy of the Barrande types in Prague during the Summer of 1964. K.E.C.

early offshoot of this line is probably represented by forms like *Heckericystis*. This genus has apparently a holomerous proximal stele; it may have evolved by consolidation of numerous bands of smaller plates such as those in *Dendrocystis sedgwicki*, or by dimeres (laterals) and sagittals ankylosing. Thecal and brachial similarities between *Heckericystis* and *Dendrocystites* are fairly evident and the former genus probably represents a side branch from pre-*Dendrocystites barrandei* forms. (See Text-fig. 11.)

The tetramerous proximal stele of the unnamed Upper Cambrian fossil of Ubahgs may lead to the Upper Ordovician genus *Dendrocystoides* Jaekel which is in stele configuration similarly organized. From near the base of this tetramerous stock the *Dendrocystites vidali* occurrence in the Lower Ordovician, although not well known morphologically, suggests that here we may be close to the ancestral stock of three families. The thecal arrangement in this offshoot must have retained the flexible polyplated condition, but the increased efficiency of its locomotor organ would selectively favor the trend toward bilateral thecae.

However, more mobility of the proximal stele did not inevitably lead to bilateralism of the whole organism.¹¹ In the Lower Devonian Rutroclypeidae (Australia and Germany) a highly flexible tetramerous proximal stele is associated with a circular, biplanate (coinlike) many plated theca. It is clear that here is an alternate adaptional form established upon an archaic thecal scheme. The spinosity of the Australian rutroclypeids bespeaks their terminal and highly specialized nature in the Soluta. Still they must be viewed as specialized anachronisms in the order.

Unfortunately, the connecting links between the Devonian Rutroclypeidae and these ancient forebears are not yet known. However, this is hardly strange, considering the likely vicissitudes of loosely plated organisms under ordinary conditions of sedimentation and preservation. It would be unlikely that the Rutroclypeidae evolved from any of the three tetramerous solute lineages, the Syringocrinidae, Iowacystidae or the *Dendrocystoides* radicle of

¹¹The solutan theca shows a general bilateralism superimposed upon a fundamental asymmetry, but there is never striking symmetry of the plates either in form or distribution.

the Dendrocystitidae as now constituted. [Incidentally, when re-studied, no doubt *Dendrocystoides scotica* (Bather) will become the basis of a new family. Its differences from the other Dendrocystitidae are famillous as now understood.]

These tetramerous dendrocystitids, e.g., *Dendrocystoides scotica*, have a more or less fixed and specialized (*viz.* the anti-brachial structure) thecal shape and seem to lack any sign of a median stele. However, here as commonly elsewhere in explosions of carpoid morphology, we may either have inadequate documentation in the record, or insufficient attention to stele detail by previous authors. The other families have well-defined marginal plates and fixed plate patterns, both of which are advanced specializations. For lack of further evidence, therefore, the rutroclypeids must be considered to have evolved early in the phylogeny of the order and to have conservatively retained their primitive traits into Devonian time.

From this early tetramerous line, perhaps even off the archaic rutroclypeid radicle, evolved the two North American families. By progressive marginal regularization of the thecal plates and differentiation of an upper and lower thecal surface, the basal stock of these two families developed an outer rim of marginal plates with concomitant somatic plate differentiation on the two surfaces. Along with this the brachiole migrated toward and onto the upper surface.

The Syringocrinidae are closer to this generalized tetramerous ancestry than the Iowacystidae and show an intermediate level of development. Indicative of this is the retention here of the large number of loosely articulating dorsal somatic plates. Bilateral symmetry of the plates is incomplete here, especially when compared with the *Iowacystis*. The stele traits are somewhat generalized; sagittal insertion of plates is manifest, and a fused median zone of dimeres and dorsal sagittals creates the specialized dendrostyloid apparatus which is unique. This probably correlates with the 90 degree functional rotation of the distal stele to bring the lateral sutural flanges of the left dimeres to a ventral position in life, perhaps thus serving a styloid function analogous to that of the styloid process in the Mitrata.

The Iowacystidae represent the most advanced specialized level

of development in the order. With the exception of the polyplated somatic area of the upper surface, the plates are completely regularized. The marginals are distinct and, even in their extent over both surfaces, marginal and ventral bilaterality is broken only by the anal structure and the accompanying disturbance of surrounding plates. This level of development closely approaches the mitrates in degree of regularization and bilaterality.¹² The arm has migrated not only to the upper surface but some distance proximally, and the adjoining distal plates have been considerably modified to receive and support it. As shown in the phylogenetic chart (Text-fig. 11), the Iowacystidae may well be highly specialized derivations of the same tetramerous stock as the Syringocrinidae. These American Ordovician expressions are by all odds the most specialized of Soluta and both show the same trends toward mitrate and rhipidocystian simulation. However, the two American genera have each pursued long independent evolution. In addition to the high degree of thecal regularization, the stele has undergone significant change. The number of proximal segments has been reduced to seven as compared to the approximate 20 of the first known tetramerous solute of the Cambrian.¹³

This trend toward numerical reduction in the elements of the proximal stele is in keeping with other younger genera, *viz.*, *Rutro-clypeus* and *Dendrocystoides*. Along with this reduction has come a similar reduction in the median stele so that in the Upper Ordovician and younger genera distal and proximal stele sharply intergrade.

Syringocrinus has also shown the tendency for reduction in the proximal stele but has retained and greatly specialized the median stele. In the same vein the distal stele, though generalized, has adopted very specialized characteristics, *viz.*, flanges, nodes, and

¹²*Dalejocystis casteri* Prokop, 1963, in thecal outline bears a remarkable resemblance to *Iowacystis* as both are sagittate, but the former is more symmetrical in its plate arrangement. This mitrate, from Bohemia, is the youngest of all known carroids and is found in the Daleje shales, Middle Devonian (Eifelian) of Bohemia.

¹³*Dendrocystites vidali* Thorval (1935) has, according to Ubaghs, at least 25, and perhaps more proximal stele segments. It is found in the Lower Ordovician or Upper Cambrian of France.

axial twisting for deployment of the flanges and increased "swimming" efficiency in the laterally moving organ. *Iowacystis*, on the other hand, has followed the usual course of distal stele simplification but has curiously retained the ventral saggittal intercalates.

The one feature, however, that shows the Iowacystidae to be highly specialized, perhaps over all other traits, is the evidence for an orderly "tissue" system on the dorsal somatic and marginal plates.

Throughout the entire order the arm is conservative and in all known genera shows few, if any, significant differences other than minor relative proportions of plate and groove size and overall length.

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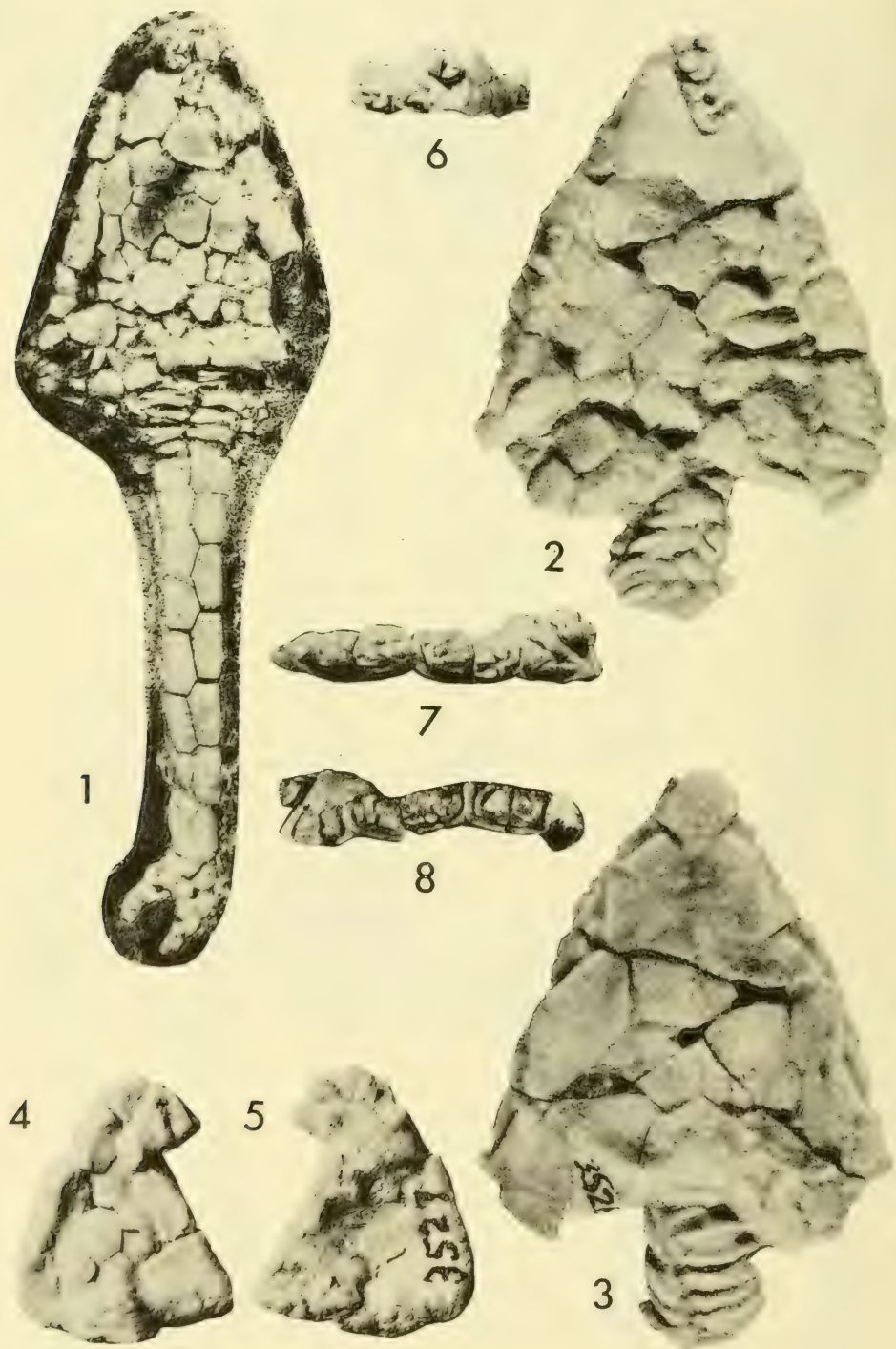
PLATES

The cost of the reproduction of the plates and text figures has been met by a grant from the Graduate School of the University of Cincinnati.

EXPLANATION OF PLATE 16

<i>Figure</i>	<i>Page</i>
1. Syringocrinus sinclairi Parsley and Caster, sp. nov.	121, 138
Holotype GSC 17520, Sherman Fall formation (Middle Trenton), Lakefield, Ontario; X2.	
2. Syringocrinus sinclairi Parsley and Caster, sp. nov.	128, 138
Paratype I, GSC 17521, Upper Trenton group, Chateau Richer, Quebec; X3.	
3. Syringocrinus paradoxicus Billings, 1859.	118
A crushed proximal stele with left and dorsal series of the den- drostyloid visible. Sutural flanges and nodes are visible in the left series. Holotype, GSC 1521, Sherman Fall beds (Middle Trenton), Beauport, Quebec; X3.	
4. Syringocrinus sinclairi Parsley and Caster, sp. nov.	121, 140
Paratype VI, GSC 17523, Upper Trenton group, Chateau Richer, Quebec; X3.	
5. Syringocrinus sinclairi Parsley and Caster, sp. nov.	121, 139
Paratype II, GSC 17521a, Upper Trenton group, Chateau Richer, Quebec; X3.	
6. Syringocrinus sinclairi Parsley and Caster, sp. nov.	121, 140
Paratype VIII, GSC 17524, Upper Trenton group, Chateau Richer, Quebec; X3.	
7. Syringocrinus sinclairi Parsley and Caster, sp. nov.	121, 140
Paratype V, GSC 17522b, Middle Trenton group, Lakefield, Ontario; X2.	
8. Syringocrinus sinclairi Parsley and Caster, sp. nov.	121, 139
Paratype IV, GSC 17522a, Middle Trenton group, Lakefield, Ontario; X2.	
9. Syringocrinus sinclairi Parsley and Caster, sp. nov.	121, 139
Paratype III, GSC 17522, Middle Trenton group, Lakefield, Ontario; X3.	
10. " Dendrocystitid " Ubaghs, 1963.	154
Lateral view of a compressed proximal and distal stele, note the ridge on the proximal stele marking the lateral suture of each segment. USNM 143240, Whipple Cave formation, Upper Cambrian, Sawmill Canyon, Nevada; X2.	
11. Syringocrinus sinclairi Parsley and Caster, sp. nov.	121, 140
Paratype VIII, GSC 17525, Middle Trenton, Lakefield, Ontario; X2.	





EXPLANATION OF PLATE 17

Specimens are from the Fort Atkinson limestone member of the Maquoketa shale, Upper Ordovician (Richmond) in age. All specimens were found in the Fort Atkinson quarry, Winneshiek County, Iowa.

Figure

Page

1. **lowacystis sagittaria** Thomas and Ladd, 1926143
Dorsal view of nearly the complete animal. The "G," "O" and dorsal somatic plates are well preserved. Plates at the apex of stele are spread from their normal tapering configuration. Note ridges on the proximal stele. Syntype, SUI 3525; X2.
2. **lowacystis sagittaria** Thomas and Ladd, 1926143
Dorsal view of a theca and proximal stele. Note the remnant of the arm and the surrounding "G", "Y", and "O" plates. Syntype, SUI 3526; X3.
3. **lowacystis sagittaria** Thomas and Ladd, 1926 143
Ventral view of a theca and proximal stele. The arcuate grooves and their parallel ridges are seen in their ventral expression on the marginals. Fine aligned pustules are visible on the *AM* and *SM* marginal plates. Note the prominent ridge on the basal median marginal and the absence of the platted anal structure. Syntype, SUI 3526; X3.
- 4, 5. **lowacystis sagittaria** Thomas and Ladd, 1926.143
Ventral face (4) of a small theca showing some of the pustular prosopon and some of the anal apparatus. Note the embayment for the proximal stele. Dorsal face (5) is poorly preserved. Syntype, SUI 3527; X3.
6. **lowacystis sagittaria** Thomas and Ladd, 1926. 143
Anterior view showing the relationship of the arm to plates "G", "Y" and *AM*. Note the anterior elevated grooves on either side of the arm. Syntype, SUI 3526; X2.
7. **lowacystis sagittaria** Thomas and Ladd, 1926.143
A lateral view of the right side of specimen SUI 3526. Note the relationship of the brachiole to the "O" plate. Also note the arcuate groove and ridge system and the trends of the nodes and grooves dorsal to it. Syntype, SUI 3526; X2.
8. **lowacystis sagittaria** Thomas and Ladd, 1926.143
A lateral view of the left side of specimen SUI 3526. The prosopon is also clearly defined on this side. Note the zigzag suture between the "G" plate and the adjacent marginal plates. Syntype, SUI 3526; X2.

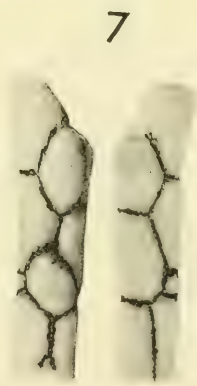
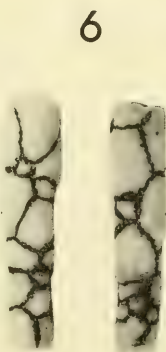
EXPLANATION OF PLATE 18

Specimens are from the Fort Atkinson limestone member of the Maquoketa shale, Upper Ordovician (Richmond) in age. All specimens were found in the Fort Atkinson quarry, Winneshiek County, Iowa.

Figure

Page

1. **lowacystis sagittaria** Thomas and Ladd, 1926.143
Dorsal view of a theca, proximal stele and part of the first segment of the distal stele. Note the development of the anal apparatus. Syntype, SUI 3528; X3.
2. **lowacystis sagittaria** Thomas and Ladd, 1926.143
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**UPPER CRETACEOUS AND PALEOCENE PLANT
MICROFOSSILS AND PALEOCENE
DINOFLAGELLATES AND HYSTRICHOSPHAERIDS
FROM NORTHWESTERN SOUTH DAKOTA**

By

EDWARD A. STANLEY
University of Georgia

September 10, 1965

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UPPER CRETACEOUS AND PALEOCENE PLANT MICROFOSSILS AND PALEOCENE DINOFLAGELLATES AND HYSTRICHOSPHAERIDS FROM NORTHWESTERN SOUTH DAKOTA

EDWARD A. STANLEY

Department of Geology, University of Georgia
Athens, Georgia

ABSTRACT

Palynological studies of the Upper Cretaceous and lower Tertiary sediments exposed in four stratigraphic sections in Harding County, South Dakota, a portion of the northern part of the Great Plains of the United States, have been undertaken in order to 1) establish the types of plant microfossils present; 2) infer the botanical affinities of the species encountered and the climatic conditions represented by these species; 3) establish a palynological zonation that would permit correlation of the sections with one another and with sediments of similar age in other areas.

Eighty species of plant microfossils are assigned to 53 genera; 51 species and 3 genera are described as new. Among the 19 species of dinoflagellates and hystrichosphaerids encountered and assigned to 11 previously described genera, 9 species are described as new. Many of the species of both the plant microfossils and the fossil plankters have also been described from other areas of the world such as western Europe, Siberia, and Australia.

Based on the distribution of plant microfossils, the Crow Butte section of Late Cretaceous age is divided into three zones whereas the North Cave Hills section of Paleocene age is subdivided into two zones. The Twin Butte section which was thought to contain the Cretaceous-Tertiary boundary is shown to be correlative with the North Cave Hills section and, in its entirety, is Paleocene in age. The Cannonball section, on the bases of pollen and spores and also dinoflagellates and hystrichosphaerids is shown to be of Paleocene age.

Many of the plant microfossils from the Paleocene sections are assigned to extant genera and on these data, a temperate climate is postulated for the area during Paleocene time. Few of the Upper Cretaceous plant microfossils are assignable to extant genera and, therefore, there are insufficient data for any climatic interpretation during Late Cretaceous time.

The following genera are described as new: *Aenigmapollis*, *Pseudotricolpites*, and *Triolapollis*. New species are: *Deflandrea dakotensis*, *D. magnifica*, *D. microgranulata*, *D. pannucea*, *Wetzeliella pilata*, *W. rugosa*, *Spinidinium densispinatum*, *S. microceratum*, *Cyclonephelium lemniscatum*, *Foveosporites triangulus*, *Foveosporites cyclicus*, *Hamulatisporites amplus*, *Cingulatisporites dakotensis*, *C. radiatus*, *Gleichenia triangula*, *Hymenophyllumsporites furcosus*, *Leptolepidites tenuis*, *Azolla cretacea*, *Schizaea plectilis*, *S. triangula*, *Reticulatasporites cristatus*, *Schizosporites complexus*, *S. laevigatus*, *S. microfoveatus*, *S. scabratus*, *Cycadopites giganteus*, *C. scabratus*, *Picea rara*, *Pinus ruginosa*, *P. semicircularis*, *Podocarpus maximus*, *Sequoiapollenites paleocenicus*, *Ephedra voluta*, *Rhoipites crassus*, *R. globosus*, *R. pisinnus*, *Alnus quaternaria*, *A. trina*, *Betula infrequens*, *Carpinus subtriangula*, *Corylus granilabrata*, *Pachysandra cretacea*, *Caprifoliipites longus*, *Ericaceipollenites rallus*, *Carya paleocenica*, *Engelhardtia microfoveolata*, *Pterocarya grandis*, *P. levis*, *Anacolisidites rotundus*, *Fraxinipollenites variabilis*, *Quercoidites genustriatus*, *Cupanicidites speciosus*, *Vitis affluens*, *Aenigmapollis polyformis*, *Pseudotricolpites reticulatus*, *Triolapollis scabratus*, *Triatriopollenites pseudomagnificus*, *Tricolpites bathyreticulatus*, *T. hians*, *T. parvus*.

INTRODUCTION AND SCOPE

The lignites in northwestern South Dakota achieved considerable importance within the last 15 years because of the small percentage of uranium they contain. This uranium was found to be

concentrated in some beds leaving others barren and, therefore, at the time when this study was initiated, correlation of these lignitic beds was thought to be important. Recent work by the U.S. Geological Survey suggests an epigenetic origin for the uranium. The study by Denson, *et al.*, (1959, p. 31) "indicate that the uranium in the lignite is independent of the age of the formation in which the lignite occurs but is very closely related to the topographic position of the widespread unconformity at the base of a thick sequence of tuffaceous rocks which at one time covered most of the region." The economic value of the correlations presented in this paper is somewhat lessened although still believed to be important.

Because of the marked lateral lithologic changes of the non-organic sediments and the lenticular nature of many of the lignites (Brown, 1962, p. 12; and more specifically Denson, *et al.*, *op. cit.*, p. 18) correlation of these sediments, in some cases, has proven difficult. In addition, an old academic problem reappeared; namely, are all the lignites early Tertiary in age or are some Late Cretaceous and, if so, where should the boundary be placed? Although plant megafossils and dinosaur remains appear to be fairly common in eastern Wyoming, they are much more infrequent in northwestern South Dakota and are of limited value. Geologists of both the U.S. Geological Survey and the U.S. Atomic Energy Commission have worked in the area for several years, and there still is no precise agreement on where to place the Cretaceous-Tertiary boundary (see Brown, *op. cit.*, p. 9; Denson, *et al.*, *op. cit.*, pp. 16-17).

Because this study is the first of its kind that deals with the area, it was felt that it should be of a broad nature with the following objectives.

1. Establishment of the fossil pollen and spores present in the Upper Cretaceous-lower Tertiary strata.
2. Inference of the botanical affinities of the species encountered.
3. Inference of climatic conditions based on the plant microfossil affinities.
4. Establishment of a palynological zonation that would permit correlation of the measured sections with one another.
5. Comparison of these data with other palynological and paleobotanical studies of sediments of a similar age.

ACKNOWLEDGMENTS

This study is a complete revision and expansion of a dissertation problem completed several years ago (Stanley, 1960). The writer is grateful to Drs. G. O. W. Kremp and W. Spackman, Jr. who helped and advised the author with this problem. Gratitude is also acknowledged Messrs. G. N. Pipiringos and J. Gill, both of the U.S. Geological Survey, who critically read the dissertation and offered many helpful suggestions. Many of these suggestions were adopted in this revised work. Messrs. Wayne Chisholm, at that time with the U.S. Geological Survey, and Bruno Petsch, of the South Dakota Geological Survey, offered advice on field problems on several occasions. The U.S. Atomic Energy Commission is also gratefully acknowledged for supplying funds for an assistantship to The Pennsylvania State University. It was these funds which made this investigation possible.

The revised and expanded manuscript was critically read by Dr. Alfred Traverse and most of his suggestions were adopted. In addition, Drs. Erling Dorf, William Evitt, and James Schopf read parts of the manuscript that dealt with their specialties. The writer will always be indebted to all of the above mentioned. All responsibility for any statements and interpretations made herein is fully assumed by this writer.

The writer is also indebted to both Dr. Robert A. McRorie, Director of Research for The University of Georgia, and to The University of Georgia for making funds available to cover the cost of engraving the illustrations. Finally, the writer wishes to thank his wife, Ann Allison Stanley, without whose encouragement, understanding, and unfailing help, this work never could have been completed.

DESCRIPTION OF FIELD INVESTIGATION AND
SAMPLING PROCEDURE

During the summer of 1956, approximately two weeks were spent in the field in order to make a reconnaissance survey of the area and in order to collect samples to determine which of the Upper Cretaceous and lower Tertiary formations would yield plant

microfossils upon maceration. Within this period, nine sections totaling 1136.6 feet of strata were measured. However, samples from only four sections were used in this investigation. These sections are:

1. Fort Union formation, North Cave Hills; NE. $1/9$ sec. 13, T. 21 N., R. 5 E., Harding Co., South Dakota. (Referred to in this report as the North Cave Hills section).

2. Hell Creek formation, Crow Butte; SE. $1/4$ sec. 30 and NE. $1/4$ sec. 31, T. 15 N., R. 5 E., Harding Co., South Dakota. (Referred to in this report as the Crow Butte section).

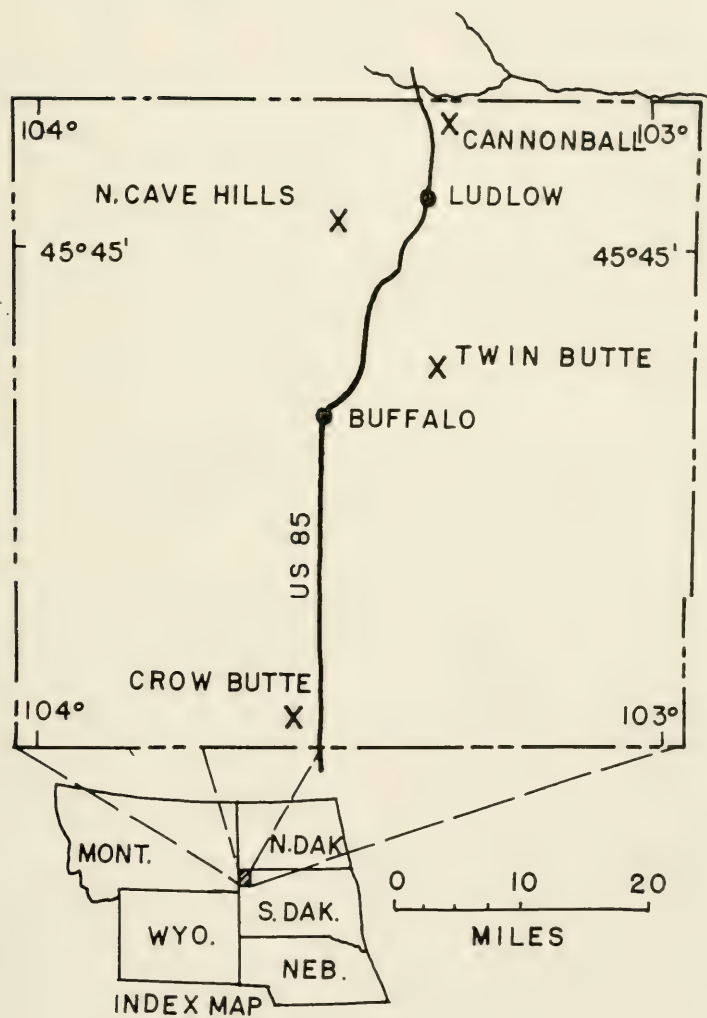
3. Upper Hell Creek formation (?) - lower Fort Union formation, Twin Butte; NC $1/9$ sec. 10, T. 19 N., R. 6 E., Harding Co., South Dakota. (Referred to in this report as the Twin Butte section).

4. Cannonball member, Fort Union formation; southern half sec. 24, T. 23 N., R. 9 E., Harding Co., South Dakota. (Referred to in this report as the Cannonball section).

The Crow Butte locality (see Text-figure 1) was suggested by Mr. Bruno Petsch, of the South Dakota Geological Survey, as a known Cretaceous section. Mr. Wayne Chisholm, at that time with the U.S. Geological Survey, suggested the North Cave Hills area for sediments of early Tertiary age. The Twin Butte section is thought by some geologists to contain the Cretaceous-Tertiary boundary and, therefore, it was included as the third section. It was hoped that the Twin Butte section would stratigraphically overlap both the North Cave Hills section and the Crow Butte section thereby giving a complete sequence of sediments representing Late Cretaceous through early Tertiary time. This did not prove to be the case as will be shown later in this report. The Cannonball section was investigated at a much later date in order to determine the types of marine microplankton present and to independently corroborate the Paleocene age of this member.

The preliminary palynological data on the three critical sections were obtained during 1957 and the early part of 1958. Much of these data presented new problems and, therefore, it was felt that several additional weeks should be spent in the field remeasuring and extending the critical sections wherever possible and also

LOCATION OF SECTIONS



Text—Figure 1

obtaining additional samples. Consequently, approximately two additional weeks were spent in the northwestern South Dakota area during the summer of 1958. Within this period, 675 feet of strata were measured or remeasured and additional samples were collected.

DESCRIPTION AND DISCUSSION OF GEOLOGY AND STRATIGRAPHY

REGIONAL GEOLOGY

Harding County, which is located in the extreme northwestern part of South Dakota, lies within the northern part of the Great Plains physiographic province of the United States. The province is generally characterized by Upper Cretaceous and Tertiary sediments of marine and continental origin. Due to the influence of the Williston Basin, strata in the western part of South Dakota generally dip in a northeasterly direction. As one goes eastward and northward, progressively younger sediments are encountered except where local structures influence the succession.

LOCAL GEOLOGY

Within Harding County, South Dakota, the oldest formation exposed is the Pierre shale of Upper Cretaceous age whereas the youngest formation, excluding Quaternary terrace deposits and Miocene-Pliocene volcanic ash deposits, is a sandstone usually referred to the Arikaree formation of Miocene age. Except on the minor structures present within the county, all formations generally dip northeasterly. The amount of the dip of the various formations usually ranges between 7 to 68 feet per mile, or less than one degree of inclination (Brown, 1952, p. 14; Winchester, *et al.*, 1916, p. 36). Consequently, the strata within the area may be considered to be essentially horizontal.

The only recognized major unconformity in the region lies at the base of the Oligocene White River formation. The folding of the minor flexures and the general easterly tilting of the Upper Cretaceous and Paleocene formations and the consequent erosion of these formations all occurred before the deposition of the White River sediments (Baker, 1952, p. 13). The White River formation

is found to lie unconformably on the lower part of the Hell Creek formation in the Short Pine Hills, on the Ludlow member of the Fort Union formation at Slim Buttes and on the Tongue River member of the Fort Union formation in the Cave Hills (Brown, 1952, p. 14).

Several synclines and anticlines are present within the county. They all trend more or less north-south and generally tend to parallel the strike of the strata. These structures account for the variations from the outcrop pattern that one would expect to get on the flanks of a basin.

DESCRIPTION OF THE FORMATIONS SAMPLED

The stratigraphic relationships of the formations sampled for plant microfossils are shown in Text-figure 2.

HELL CREEK FORMATION

The Hell Creek formation was named by B. Brown (1907) for exposures along Hell Creek, Garfield County, Montana. This formation name has been widely used for the late Upper Cretaceous continental strata in South Dakota. The Hell Creek formation is presently thought to be contemporaneous in age with the Lance formation in eastern Wyoming and the Laramie formation in the Denver Basin. Because of the dull, dark-gray color exhibited by characteristic or typical outcrops of this formation, it was frequently referred to in the early literature as the "sombre-beds." This name is still occasionally used.

Within Harding County, South Dakota, the Hell Creek formation consists of "loess, bentonite, loose volcanic ash and a few thin channels of fine-grained sands of the same composition as the underlying Fox Hills" (Baker, 1952, p. 7). In addition, Baker (*ibid.*, p. 7) included a "few thin brownish carbonaceous streaks and some thin lignites, the latter in the upper part" of the Hell Creek formation. The thickness of this formation, as given by Baker, is 425 feet.

The Hell Creek formation was sampled at Crow Butte in the southcentral part of Harding County. Here the late Upper Cretaceous sediments consist of dark brown clays, gray bentonitic-like

clays, mudstones and siltstones and light, fine-grained channel sands. Many of the siltstones and mudstones are finely laminated.

TEXT-FIGURE 2
STRATIGRAPHIC RELATIONSHIP OF THE FORMATIONS SAMPLED

PALEOCENE	TONGUE RIVER MEMBER (600 FT.±)
	CANNONBALL MEMBER (0-350 FT.±)
	LUDLOW MEMBER (300-350 FT.±)
UPPER CRETACEOUS	HELL CREEK FORMATION (450 FT.±)

The total thickness of this section was measured to be 212 feet. On the basis of the lithology and the lithologic relationships of the sediments, it is suggested that the Crow Butte section represents a fluvial environment which is a lateral equivalent of the typical gray sombre beds commonly assigned to the Hell Creek formation.

Invertebrate and vertebrate fossils in the Crow Butte section were not observed. Fossil pollen and spores, however, were discovered in many of the sediments. Some of these plant microfossils proved to be typically known Cretaceous types whereas others are new species.

FORT UNION FORMATION

The Fort Union formation was originally named by Meek and Hayden (1862) for exposures near Old Fort Union, then located at the mouth of the Yellowstone River near what is now the town of Buford, North Dakota. Meek and Hayden (1862, p. 433) wrote that the Fort Union formation "... overlies Fox Hills beds and underlies Wind River deposits. Occupies whole country around Fort and extends north into British possessions unknown distances and southward to Fort Clark."

At the present time, the Fort Union formation is usually divided into four members: the Ludlow Lignitic member, which eastward interfingers with the marine Cannonball member; the Tongue River member; and the Sentinel Butte member. The Ludlow and Cannonball members were sampled and are discussed

separately below. The Tongue River member was also sampled, but the samples proved to be barren. The Sentinel Butte member, on the other hand, was not sampled. Therefore, both the Tongue River and Sentinel Butte members are omitted from any further discussion.

LUDLOW MEMBER

The Ludlow member or, as it is more frequently referred to, the Ludlow Lignitic member of the Fort Union formation, was named by Lloyd and Hares (1915) for exposures near the town of Ludlow, Harding County, South Dakota. When the member was named, a type section was not designated by Lloyd and Hares, and since then no type or standard section has been proposed.

Following the suggestion of Mr. W. Chisholm, then with the U.S. Geological Survey, the Ludlow Lignitic member of the Fort Union formation was sampled in the southern part of the North Cave Hills. Several gullies were examined and the gully where the strata were thought to be best exposed was finally chosen. A composite section consisting of sections herein listed as I, E, D and B was measured (Appendix). Correlation of the separate units of the composite section was effected by using lignite seams and other distinctive beds as marker horizons. The total thickness of the strata assigned to the Ludlow is approximately 325 feet. The thickness of the Ludlow is given in the literature as being between 300 and 350 feet.

The sediments placed in the Ludlow Lignitic member consist of thin lignites separated by massive, poorly cemented, very fine-grained sandstones. A considerable amount of bentonite was found to be mixed with the fine-grained sandstones and also was found to occur as separate beds. No less than 16 distinct lignite horizons were observed in the section measured. Baker (1952, pp. 11, 12) believed that many of the fine sands that are found between the lignites are wind deposited, "much of which settled in shallow ponds, bogs and marshes . . ." The massive nature of the sandstones and their very fine grain size would seem to support this.

CANNONBALL MEMBER

The Cannonball member of the Fort Union formation was

named by E. R. Lloyd (1914) for exposures along the Cannonball River in Morton County, North Dakota. This member is exclusively marine and commonly regarded as being the lateral equivalent of the Ludlow Lignitic member of the Fort Union formation. Although the thickness of the Cannonball member is between 300 and 350 feet at the type locality, only 42 feet have been recorded in Harding County (Winchester, *et al.*, 1916, p. 23). About 47 feet of sediments are assigned to the Cannonball member in this report.

Numerous marine invertebrate fossils have been described from the Cannonball member. It has been shown by Fox and Ross (1942) that there is a similarity in the Foraminifera of the Cannonball and those found in the Midway group (Paleocene) of the Gulf Coast.

DESCRIPTION OF PREPARATION METHODS AND ANALYTICAL PROCEDURES

MACERATION

Two major types of sediments were collected for palynological examination. One type consists chiefly of organic material whereas the other type is siliceous in composition. Each type had to be macerated differently in order to free the pollen and spore exines from the matrix. The maceration methods used in this study can be found in such standard reference works as Sitter (1955), de Jekhowsky (1959), and Brown (1960). Briefly, the organic sediments (lignites) were processed by the H_2O_2 method (Sitter, *op. cit.*, p. 109) whereas the nonorganic sediments were demineralized in hydrofluoric acid and then oxidized if necessary. These methods were modified as necessary. Each sample has to be treated independently because no two will be exactly alike in composition and texture. The lithotypes encountered and the number and percentages of each type that yielded plant microfossils are summarized in Table 1. Examination of this table shows that all the mudstones were productive. The small number of samples in this category does not permit any generalization as to the microfossil-productivity of mudstones. The next highest microfossil yielding sediment is the lignites. As might be expected, most lignites are productive in

plant microfossils. Examination of this table also shows that the clays were better samples for this study than sandstones.

SLIDE PREPARATION

All slides employed in this investigation were prepared using glycerine-jelly or Permout as the mounting medium. Usually three slides were prepared from each sample. For samples with few grains, each slide was examined and all species encountered listed. Only one slide was carefully examined when many specimens were present on a slide. The other two slides, however, were scanned to make certain no large discrepancies existed between them and the slide that was carefully examined.

TABLE 1

PERCENT OF VARIOUS SAMPLES THAT YIELDED PLANT MICROFOSSILS

Lithology	Total Number of Samples	Number of Samples that Yielded Fossils	Percentage that were Productive
Clay	29	14	48%
Sandstone	21	5	24%
Mudstone	3	3	100%
Siltstone	1	0	0%
Lignite	57	43	77%
Other	1	0	0%
Total	112	65	61%

ANALYTICAL PROCEDURES

One-hundred pollen grains, spores, and other microfossils were identified on each slide; when one-hundred or more were present, the frequency of each species was recorded. After the one-hundred grains were identified and recorded, the remainder of the slide was scanned. Any species encountered that was not represented among the one-hundred counted microfossils was recorded. Fifty, or in

rare cases twenty-five grains were counted, recorded and then converted to 100% when a slide did not contain one-hundred plant microfossils.

In the discussion of frequency under the heading Systematic Palynology, the counts are converted, for convenience, to the frequency terms listed below.

Percent	Frequency Term
less than 6	"infrequent"
6-24	"common"
25-50	"abundant"
more than 50	"dominant"

It was found that most species remained within one frequency category, although a few varied between two frequencies.

This investigation was carried out on a Leitz Labolux microscope equipped with a Leitz No. 48 mechanical stage. All specimen coordinates given in this work are referable to this equipment. In addition, all the type specimens are encircled by a Leitz "scribe-objective" to facilitate location on other microscopes. At present, the type specimens are in the author's possession but, ultimately, they will be turned over to The United States National Museum or some other established depository for safekeeping.

CLASSIFICATION USED IN THIS WORK

POLLEN AND SPORE CLASSIFICATION

In 1960 this writer used a strictly artificial system for the classification of fossil spores and pollen. Since that time, however, much "soul-searching" has been done on the part of the writer and his views on classification and subsequent nomenclature have been modified.

The artificial system of classification has advantages in that it is based on more or less objective characteristics and, therefore, tends to be more stable. However, using the artificial system of classification with formal names in accordance with The International Code of Botanical Nomenclature does not assure or guarantee stability. As more and more knowledge is gained on the structure of pollen grains and spores, there seems to be a tendency to sub-

divide or split existing genera. The only way to avoid this is for a worker to stay outside of The Code by using a nonnomenclatural system such as that of Tschudy (1959). As long as one attempts to do detailed stratigraphic palynology, one is more or less compelled to work at the species level. For ecological purposes however, one can use "types" as in the works by Macko (1951, 1959, 1963; see especially 1963, p. 44) in which one avoids many of the nomenclatural problems associated with stratigraphic palynology.

The natural system of classification has some decided disadvantages. As pointed out by many workers, morphological information on spores and pollen of extant plants is scanty, and we certainly do not know the morphology of the spores and pollen produced by all extant plants. In spite of this, it seems to the writer that, at least outside of industry, it behooves the investigator to try to assign a fossil spore or pollen grain to a natural genus. As mentioned by Cain (1944, p. 35) "if paleontology consists merely of description and naming of fossils for purposes of cataloging and stratigraphic correlation . . . it would be a static although useful science." It is fully realized that many fossil spores and pollen grains cannot be assigned with any great degree of reliability to an extant plant genus. On the other hand, it is believed that certain other grains can be assigned to extant genera with a fair amount of confidence. Furthermore, this writer is aware that there is some danger in this method in that some fossil spores and pollen might, because of insufficient evidence at the time of assignment, be incorrectly classified. The classical paleobotanists have been assigning fossil leaves to extant genera for years without much serious criticism. One only has to examine a synonymy list in a recent systematic work such as Brown (1962) and observe the large number of apparent misassignments in the past. Through the years, however, each monograph or paper by a competent worker in the field has been more closely approaching what is thought and hoped to be the truth in classification than that of his predecessor. It is hoped that a similar situation can be achieved in palynology.

Whether an artificial or a natural method of classification and subsequently nomenclature is used is ultimately up to the individual worker (see the discussion by Traverse, 1957). Any organ of

a plant may be diagnostic of a genus or species. Commonly flowers are used by botanists whereas foresters often use leaf morphology and trunk or bud characteristics. Certainly pollen grains are characteristic at the generic and even the specific level in many groups of plants. Never is the whole individual described (physiology, genetic structure) when a new species of extant plants is described by a botanist. By the same token, never is the whole specimen used for identification purposes of extant plants. Therefore, the writer cannot agree with Potonie (1956, 1958), Kremp, Ames and Frederiksen (1959), Manum (1962), and others who maintain that organ species should be assigned only to organ genera and that a new plant species cannot be assigned to an extant genus if it is based only on pollen. With fossils, the complete specimen may not be available for description or identification, and specific identification must be made on fragmentary remains. It follows that if a palynologist who confidently feels that a fossil pollen grain has certain characters of pollen of an extant genus and enables him to place this pollen grain in that genus and describe it as a new species, then he is within his rights as a scientist in doing so. If on the other hand, another scientist feels that this same species does not have the characters of the extant genus to which it is assigned or it does not have the characters of any other extant plant taxon, then also it is his right and duty as a scientist to reassign this species to an artificial genus and put the extant generic name in synonymy. This is what Delcourt, Dettmann, and Hughes (1962) did in a recent paper. This writer does not agree with their view that there is (*op. cit.*, p. 282) “. . . considerable nomenclatural difficulty over the current Russian policy (Bolkhovitina, 1961, Samoilovitch, *et al.*, 1961, and others) of placing large numbers of fossil dispersed spore species in Recent (extant) genera. The tangle of names in microfossil nomenclature is unfortunately unavoidable in a subject developing so quickly in several different continents, but this particular, (Russian) solution seems to be totally undesirable.” However, the writer does agree with their style of listing an adequate synonymy and giving an accurate and detailed description of each species they mention. Each species will then have at least two generic names, one natural and the other artificial. Only one, how-

ever, will be correct depending on the view of the worker as to rank, position and circumscription: that is, depending on whether he believes the species should be assigned to an artificial or a natural genus.

It is held by the writer that it is not possible at the present time to assign all species of fossil spores and pollen to extant genera. On the other hand, some fossil pollen or spore species can be assigned to extant genera and this should be done whenever possible. After all, as scientists we are classifying fossil spores and pollen that were originally produced by plants that have some relationship to our present floras and from which some biological as well as geological interpretations can be made. We are not classifying letters of alphabet-soup.

In this, as in any other work of this type one has to depend heavily on the existing literature. An attempt was made to examine all pertinent works before any decision on the taxonomic position of any of the groups studied was reached. For each taxon listed in this work the reader will find what is hoped to be a fairly complete synonymy list. Because of the vast amount of palynological literature appearing in a large number of journals, some works undoubtedly have been overlooked. With few exceptions noted all the references listed were examined. When a taxon is assigned to an extant genus, all the references used giving pollen descriptions of that genus are listed in the synonymy in order that the reader may have the sources readily available to him. In addition, approximately 2000 species of modern pollen and spore slides are in the author's personal collection. Although this collection is not large by some standards, it did prove to be an invaluable source of reference material. When a fossil pollen or spore species was assigned to an extant genus, usually reference material of several species of that genus was available for comparative purposes supplementing the literature. In spite of all the precautions taken, some errors in classification undoubtedly occur. As these are detected a systematic procedure should be followed to correct them.

DINOFLAGELLATE-HYSTRICHOSPHAERID CLASSIFICATION

The naming of fossil dinoflagellates has commonly been treat-

ed under the International Code of Zoological Nomenclature. Although some extant dinoflagellates such as *Gymnodinium* have characteristics common to both the plant and the animal kingdom, in most modern works the dinoflagellates are commonly placed under the algae. In several recent papers by Downie, Williams, and Sarjeant (1961), Evitt (1961, 1963a, 1963b), and Downie, Evitt, and Sarjeant (1963), it has been suggested that for phylogenetic purposes and uniformity, fossil dinoflagellates also be transferred to the plant kingdom. If living dinoflagellates are commonly assigned to the plant kingdom, then it seems reasonable to assign fossil members of this group to the same kingdom. It is believed that few workers will disagree with this.

Hystrichosphaerids have also, up till recently, been dealt with by some workers under the zoological code. On the question of affinities of the hystrichosphaerids there appears to be no general agreement at present as to whether they represent a monophyletic (Eisenack, 1954, 1962, 1963) or a polyphyletic (Deflandre, 1947) group. For a detailed history of the hystrichosphaerid problem, the reader is referred to the excellent papers on the subject by Sarjeant (1960, 1961, 1963). Most present day workers would agree that at least some of these problematical organisms have affinities with the algae. Eisenack (1963, p. 134) pointed out that this algal relationship was suspected as early as 1838 by von Stein. Evitt (1961, 1963a, 1963b) presented some, although not conclusive data that at least some of the hystrichosphaerids are dinoflagellate cysts. On the basis of these data, Downie, Evitt, and Sarjeant (1963) transferred many of the hystrichosphaerids to the plant kingdom. The hystrichosphaerids that these workers could not confidently assign to the plant kingdom are placed in a new *incertae sedis* group, the Acritarcha.

The fossil dinoflagellates described in this paper are assigned to the Division Pyrrophyta. The fossil hystrichosphaerids (*sensu lato*) are only tentatively assigned to the Division Pyrrophyta. The zoological familial endings are retained to avoid redescribing and emending these groups at this time. The descriptive terminology proposed by Evitt (1961) is adopted in this work. However, the revised classification published by Evitt (1963a, 1963b) and Downie,

Evitt, and Sarjeant (1963) is not used chiefly because it appeared too late to be included in this study.

DISCUSSION OF STRATIGRAPHIC SIGNIFICANCE OF PALYNOLOGICAL DATA

GENERAL DISCUSSION

The number and percentage of the large plant groups in the Cretaceous Crow Butte section and the Tertiary North Cave Hills section are shown in Table 2. Perhaps the most significant part of these data, in comparing the Cretaceous and the Tertiary sections, is that there is a marked increase in the number of gymnosperms and also a noted decrease in the number of the *incertae sedis* in the Tertiary section. The angiosperms and lower plant groups show little difference between these two sections of different age. The significance of these data is not fully interpretable because the assignment of the unknowns (*incertae sedis*) to any one or more of the known groups could radically change the percentages of the latter.

TABLE 2

TOTAL NUMBER OF SPECIES AND PERCENTAGES OF
SPECIES DISTRIBUTED AMONG THE MAJOR PLANT
GROUPS

	CROW BUTTE		TWIN BUTTE, +	
	No.	%	No.	%
Ferns and Mosses	16	38%	22	41%
Gymnosperms	4	9%	8	15%
Angiosperms	10	23%	15	28%
Incertainae sedis	13	30%	8	15%

A list of the species described in this paper is given in Table 3. It should be mentioned that this list is not complete as there are many more species of plant microfossils present in the Upper Cretaceous-lower Tertiary sediments in the northwestern South Dakota area. A complete study would take several life-times. It is hoped that most of the more frequently occurring plant microfossils, as well as some of the rarer ones, are included in this work.

TABLE 3
LIST OF SPECIES DESCRIBED

Division Pyrrhophyta

Family Deflandreidae Eisenack, 1954

Genus *Deflandrea* Eisenack, 1938

Deflandrea dakotensis, n. sp.

Deflandrea magnifica, n. sp.

Deflandrea microgranulata, n. sp.

Deflandrea pannucca, n. sp.

Deflandrea speciosa Alberti

Genus *Wetzelicella* Eisenack, 1938

Wetzelicella pilata, n. sp.

Wetzelicella rugosa, n. sp.

Family Gymnodiniidae Bergh

Genus *Gymnodinium* Stein emend. Kofoid & Swezy, 1921

Gymnodinium nelsonense Cookson

Incertae Familiae

Genus *Palacocystodinium* Alberti, 1961

Palacocystodinium golzowense Alberti

Genus *Spinidinium* Cookson & Eisenack, 1962

Spinidinium densispinatum, n. sp.

Spinidinium microceratum, n. sp.

Division Pyrrhophyta (provisional assignment)

Family Hystrichosphaeridae O. Wetzel, 1933

Genus *Arcoligera* Lejeune-Carpentier, 1938

Arcoligera aff. *A. senonensis* Lejeune-Carpentier

Genus *Cyclonephelium* Deflandre & Cookson emend. Cookson & Eisenack, 1962

Cyclonephelium lemniscatum, n. sp.

Genus *Hystrichosphaeridium* Deflandre emend. Eisenack, 1958

Hystrichosphaeridium colligerum Deflandre & Cookson

Hystrichosphaeridium inodes Klumpp

Hystrichosphaeridium tubiferum (Ehrb.) Deflandre

Genus *Micrhystridium* Deflandre, 1937

Micrhystridium piliferum Deflandre

Family Pterospermopsidae Eisenack, 1954

Genus *Pterospermopsis* W. Wetzel, 1952

Pterospermopsis australiensis Deflandre & Cookson

Division Chlorophyta

Family Hydrodictyaceae

Genus *Pediastrum* Meyen, 1829

Pediastrum cf. *P. boryanum* (Turpin) Meneghini

Division Bryophyta

Class Musci

Family Sphagnaceae

Genus *Sphagnum* (Dill.) L., 1753

Sphagnum antiquasporites Wilson & Webster

Sphagnum australe (Cookson) Drozh.

Sphagnum australe parvum (Cookson), n. comb.

Sphagnum regium Drozh.

Division Tracheophyta

Class Lycopodiaceae

Family Lycopodiaceae (provisional assignment)

- Genus *Foveasporis* Krutzsch, 1959
 - Foveasporis triangulus*, n. sp.
- Genus *Foveosporites* Balme, 1957
 - Foveosporites canalis* Balme
 - Foveosporites cyclicus*, n. sp.
- Genus *Hamulatisporis* Krutzsch, 1959
 - Hamulatisporis amplus*, n. sp.
 - Hamulatisporis hamulatis* Krutzsch
- Family Selaginellaceae (provisional assignment)
 - Genus *Cingulatisporites* Pflug emend. Potonie, 1956
 - Cingulatisporites dakotaensis*, n. sp.
 - Cingulatisporites radiatus*, n. sp.
- Class Filicineae
 - Family Dicksoniaceae (provisional assignment)
 - Genus *Alsophilidites* Cookson ex Potonie, 1956
 - Alsophilidites kerguelensis* Cookson
 - Family Gleicheniaceae
 - Genus *Gleichenia* Smith, 1793
 - Gleichenia circinidites* Cookson
 - Gleichenia triangula*, n. sp.
 - Family Gleicheniaceae (provisional assignment)
 - Genus *Cardioangulina* Mal. emend. Potonie, 1960
 - Cardioangulina diaphana* (Wilson & Webster), n. comb.
 - Family Hymenophyllaceae (provisional assignment)
 - Genus *Hymenophyllumsporites* Rouse, 1957
 - Hymenophyllumsporites furcosus*, n. sp.
 - Family Osmundaceae
 - Genus *Osmunda* L., 1753
 - Osmunda comaumensis* (Cookson), n. comb.
 - Family Polypodiaceae (provisional assignment)
 - Genus *Laevigatosporites* (Ibrahim) emend. S.W. & B., 1944
 - Laevigatosporites haardtii* (Pot. & Ven.) Thom. & Pf.
 - Laevigatosporites ovatus* Wilson & Webster
 - Genus *Leiotriletes* Naumova ex Potonie & Kremp, 1954
 - Leiotriletes pseudomaximus* (Pf. & Thom.), n. comb.
 - Genus *Leptolepidites* Couper, 1953
 - Leptolepidites tenuis*, n. sp.
 - Family Salvinaceae
 - Genus *Azolla* Lam., 1783
 - Azolla cretacea*, n. sp.
 - Family Schizaeaceae
 - Genus *Anemia* Swartz, 1806
 - Anemia radiata* (Krutzsch), n. comb.
 - Anemia tricornitata* (Weyland & Greifeld), n. comb.
 - Genus *Schizaea* Smith, 1798
 - Schizaea plectilis*, n. sp.
 - Schizaea triangula*, n. sp.
 - Family Schizaeaceae (provisional assignment)
 - Genus *Triplanosporites* Pflug, 1952
 - Triplanosporites sinuosus* Pflug
 - Genus *Toroisporis* Krutzsch, 1959
 - Toroisporis major* (Pflug), n. comb.
 - Incertae Familiae-spores
 - Genus *Reticulatasporites* Leschik, 1955
 - Reticulatasporites cristatus*, n. sp.

Genus *Schizosporis* Cookson & Dettmann, 1959

Schizosporis complexus, n. sp.

Schizosporis laevigatus, n. sp.

Schizosporis microfoveatus, n. sp.

Schizosporis scabratus, n. sp.

Class Gymnospermae

Order Cycadales

Family Cycadaceae (provisional assignment)

Genus *Cycadopites* Wodehouse ex Wilson & Webster, 1946

Cycadopites giganteus, n. sp.

Cycadopites scabratus, n. sp.

Order Coniferales

Family Cupressaceae

Genus *Thuja* L., 1753

Thuja ? *hiatus* (Potonie), n. comb.

Family Pinaceae

Genus *Picea* Dietr.

Picea rara, n. sp.

Genus *Pinus* (Tourn.) L., 1753

Pinus ruginosa, n. sp.

Pinus semicircularis, n. sp.

Family Pinaceae (provisional assignment)

Genus *Laricoidites* Potonie, 1938

Laricoidites magnus (Potonie) Potonie

Family Podocarpaceae

Genus *Podocarpus* L'Herit, 1807

Podocarpus maximus, n. sp.

Family Taxodiaceae (provisional assignment)

Genus *Sequoiapollenites* Thiergart, 1938

Sequoiapollenites paleocenicus, n. sp.

Order Gnetales

Family Ephedraceae

Genus *Ephedra* Tourn. ex L., 1737

Ephedra voluta, n. sp.

Class Angiospermae

Family Anacardiaceae (provisional assignment)

Genus *Rhoipites* Wodehouse, 1933

Rhoipites crassus, n. sp.

Rhoipites globosus, n. sp.

Rhoipites pisinnus, n. sp.

Family Betulaceae

Genus *Alnus* (Tourn.) Hill, 1756

Alnus quaternaria, n. sp.

Alnus trina, n. sp.

Genus *Betula* (Tourn.) L., 1753

Betula infrequens, n. sp.

Genus *Carpinus* (Tourn.) L., 1753

Carpinus subtriangula, n. sp.

Genus *Corylus* (Tourn.) L., 1753

Corylus granilabrata, n. sp.:

Family Buxaceae

Genus *Pachysandra* Michx., 1803

Pachysandra cretacea, n. sp.

Family Caprifoliaceae (provisional assignment)

Genus *Caprifoliipites* Wodehouse, 1933

Caprifoliipites longus, n. sp.

Family Ericaceae

Genus *Ericaceoipollenites* Potonie, 1960*Ericaceoipollenites rallus*, n. sp.

Family Haloragaceae

Genus *Myriophyllum* Ponted. ex L., 1753*Myriophyllum* cf. *M. ambiguipites* Wodehouse

Family Juglandaceae

Genus *Carya* Nutt., 1818*Carya paleocenica*, n. sp.Genus *Engelhardtia* Leschen, 1825*Engelhardtia microfoveolata*, n. sp.Genus *Pterocarya* Kunth, 1824*Pterocarya grandis*, n. sp.*Pterocarya levis*, n. sp.

Family Olacaceae (provisional assignment)

Genus *Anacolosidites* Cookson & Pike emend. Potonie, 1960*Anacolosidites rotundus*, n. sp.

Family Oleaceae (provisional assignment)

Genus *Fraxinoipollenites* Potonie, 1960*Fraxinoipollenites variabilis*, n. sp.

Family Proteaceae (provisional assignment)

Genus *Proteacidites* Cookson, 1950*Proteacidites retusus* Anderson

Family Rosaceae (provisional assignment)

Genus *Quercoidites* Potonie emend. (this work)*Quercoidites genustriatus*, n. sp.

Family Sapindaceae (provisional assignment)

Genus *Cupaneidites* Cookson & Pike, 1954*Cupaneidites speciosus*, n. sp.

Family Vitaceae

Genus *Vitis* (Tourn.) L., 1753*Vitis* ? *affluens*, n. sp.

Incerta Familiaepollen

Genus *Aenigmapollis*, n. gen.*Aenigmapollis polyformis*, n. sp.Genus *Aquilapollenites* Rouse, 1957*Aquilapollenites amplus* Stanley*Aquilapollenites delicatus* Stanley*Aquilapollenites murus* Stanley*Aquilapollenites pulvinus* Stanley*Aquilapollenites reticulatus* StanleyGenus *Ovoidites* Potonie ex Thomson & Pflug, 1953*Ovoidites ligneolus* (Potonie) Thomson & PflugGenus *Pseudotricolpites*, n. gen.*Pseudotricolpites reticulatus*, n. sp.Genus *Trialapollis*, n. gen.*Trialapollis scabratus*, n. sp.Genus *Triatriopollenites* Pflug, 1953*Triatriopollenites pseudomagnificus*, n. sp.Genus *Tricolpites* Cookson ex Couper, 1953*Tricolpites bathyreticulatus* n. sp.*Tricolpites hians*, n. sp.*Tricolpites parvus*, n. sp.Genus *Wodehouseia* Stanley, 1961*Wodehouseia fimbriata* Stanley*Wodehouseia spinata* Stanley

TABLE 4. DISTRIBUTION OF PLANT MICROFOSSILS IN THE NORTH CAVE HILLS AND CROW BUTTE SECTIONS

[illegible]

TABLE 7

DISTRIBUTION OF DINOFLAGELLATES AND HYSTRICHOSPHAERIDS
IN THE CANNONBALL SECTION

	SAMPLE NUMBER	DEFLANDREA	D. dakotensis	D. magnifica	D. microgranulata	D. pannacea	D. speciosa	WETZELIELLA	W. rugosa	W. pilata	GYMNODINIUM	G. nelsonense	PALAEOCYSTODINIUM	P. polizowense	SPINDINIUM	S. densispinatum	S. microceratum	AREOLIGERA	A. aff. senanensis	CYCLONEPHELIUM	C. lemniscatum	HYSTRICHOSPHAERIDIUM	H. colligerum	H. inoides	H. tubiferum	MICRHYSTRIDIUM	M. piliferum	PTEROSPERMOPSIS	P. australiensis	PEDIASTRUM	P. cf. boryanum
LUDLOW TONGUE	18-1																														
	18-2								XX					XX						X								X			
CANNONBALL	18-3	X				X	XX	X																							X
TONGUE	18-4		XXX										X	X				X	X	X	X	XXX				X					
LUDLOW TONGUE	18-5																														
	18-5a																														

By closely examining Table 4, one can observe that there are many species of plant microfossils that are restricted to the North Cave Hills section whereas other species of plant microfossils are found only in the Crow Butte section. The Twin Butte section (Table 5) and the Cannonball section (Table 6) have many species in common with each other and also with the North Cave Hills section. The species of dinoflagellates and hystrichosphaerids in the Cannonball section are shown in Table 7. Inasmuch as these marine organisms are not found in any of the other sections studied, they are compared with the species described in the literature.

NORTH CAVE HILLS SECTION

The distribution of the pollen and spores in the North Cave Hills section is shown in Table 4. Examination of this table shows that there are many more species present in the upper part of this section than in the lower part. However, there appears to be no

sharp break in this section where a large number of species suddenly appear or disappear. Instead species appear and disappear within a more or less broad zone. A boundary subdividing this section into two zones is chosen between samples 1-18 and 1-19 (about 29 feet from the base of the measured North Cave Hills section) because of the greater concentration of plant microfossils in the upper part than in the lower part.

TABLE 8

"CHARACTERISTIC" SPECIES OF ZONE I OF THE NORTH
CAVE HILLS SECTION

Alnus trina, n. sp.
Carpinus subtriangula, n. sp.
Corylus granilabrata, n. sp.
Engelhardtia microfoveolata, n. sp.
Podocarpus maximus, n. sp.

The species of plant microfossils that are thought to be "characteristic" of Zone I of the North Cave Hills section are listed in Table 8. No species are listed for Zone II of this section. One can recognize this zone by the presence of certain long-ranging species which are "characteristic" of this section (Table 12) and the absence of species listed in Table 8.

The presence in this section (Table 12) of many plant microfossil species that have only been reported from lowermost Tertiary sediments of other areas such as Europe and the U.S.S.R. supports an interpretation of a lower Paleocene age for the Ludlow Lignitic member of the Fort Union formation.

CROW BUTTE SECTION

The distribution of plant microfossils in the Crow Butte section is shown in Table 4 and listed in Table 13. The Crow Butte section is thought to be divisible into three zones of unequal size. The species "characteristic" of each of these zones are listed in Tables 9-11. The species that are found to occur in both the Crow Butte section and in the North Cave Hills, Twin Butte, or Cannonball sections are listed in Table 14. There are only 19 species of the 80 encountered, or about 25% (Table 15) that occur in the Crow Butte section and also occur in one or more of the other sections. Twenty-seven, or 34%, of the plant microfossil species encountered

TABLE 9
 "CHARACTERISTIC" SPECIES OF ZONE I OF THE CROW
 BUTTE SECTION

Hamulatisporis hamulatis Krutzsch
Gleichenia triangula, n. sp.
Schizaea plectilis, n. sp.
Cupanacidites speciosus, n. sp.

TABLE 10
 "CHARACTERISTIC" SPECIES OF ZONE II OF THE CROW
 BUTTE SECTION

Leptolepidites tenuis, n. sp.
Anemia tricornitata (Weyland & Greifeld), n. comb.
Schizosporis microfoveatus, n. sp.
Pterocarya lewis, n. sp.
Aquilapollenites amplus Stanley
Aquilapollenites murus Stanley
Aquilapollenites pulvinus Stanley
Aquilapollenites reticulatus Stanley
Triatriopollenites pseudomagnificus, n. sp.

TABLE 11
 "CHARACTERISTIC" SPECIES OF ZONE III OF THE CROW
 BUTTE SECTION

Trialaepollis scarbratus, n. sp.

are restricted to the Crow Butte section and do not occur in any of the other sections studied. Interpretation of these data suggests that the Crow Butte section is different in age than any of the other sections. The presence of many species, that to date have been reported from only Upper Cretaceous sediments of other areas, corroborates not only an Upper Cretaceous but a late Upper Cretaceous age for the sediments of this section.

TWIN BUTTE SECTION

The Twin Butte section was originally sampled because it was reported to contain the Cretaceous-Tertiary boundary. Examination of Table 5, however, shows this not to be the case. This section did not only contain a large number of plant microfossils found in the North Cave Hills section, but it also contained at least three species that are restricted to only Zone I of this section and several other species that occur only in Zones I and II of this section. The Twin Butte samples yield no specimen that is restricted to the Crow Butte section. There are some long-ranging species present that are found

TABLE 12

POLLEN AND SPORES RESTRICTED TO THE NORTH
CAVE HILLS, TWIN BUTTE AND CANNONBALL SECTIONS

Sphagnum regium Drozh.
Foveosporis triangulus, n. sp.
Foveosporites cyclicus, n. sp.
Cingulatisporites radiatus, n. sp.
Anemia radiata (Krutzsch) n. comb.
Schizaea triangula, n. sp.
Toroisporis major (Pflug), n. comb.
Schizosporis laevigatus, n. sp.
Cycadopites scabratus, n. sp.
Picea rara, n. sp.
Pinus semicircularis, n. sp.
Podocarpus maximum, n. sp.
Laricoidites magnus (Potonie) Potonie
Sequoiapollenites paleocenicus, n. sp.
Rhoipites crassus, n. sp.
Alnus trina, n. sp.
Betula infrequens, n. sp.
Carpinus subtriangula, n. sp.
Corylus granilabrata, n. sp.
Caprifoliipites longus, n. sp.
Ericaceoipollenites rallus, n. sp.
Myriophyllum cf. *ambiguiipites* Wodehouse
Carya paleocenica, n. sp.
Engelhardtia microfoveolata, n. sp.
Pterocarya grandis, n. sp.
Fraxinoipollenites variabilis, n. sp.
Ovoidites ligneolus, (Pot.) Thom. & Pf.
Tricolpites bathyreticulatus, n. sp.
Tricolpites hians, n. sp.
Tricolpites parvus, n. sp.
Wodehouseia frimbriata Stanley

TABLE 13

POLLEN AND SPORES RESTRICTED TO THE CROW
BUTTE SECTION

Foveosporites canalis Balme
Hamulatisporis hamulatis Krutzsch
Gleichenia triangula, n. sp.
Leptolepidites tenuis, n. sp.
Anemia tricornitata (Weyland & Greifeld), n. comb.
Schizaea plectilis, n. sp.
Reticulatasporites cristatus, n. sp.
Schizosporis complexus, n. sp.
Schizosporis microfoveatus, n. sp.
Schizosporis scabratus, n. sp.
Cycadopites giganteus, n. sp.
Pinus ruginosa, n. sp.
Rhoipites globosus, n. sp.
Alnus quaternaria, n. sp.
Pterocarya levis, n. sp.

Anacolosidites rotundus, n. sp.
Proteacidites retusus Anderson
Quercoidites genustriatus, n. sp.
Cupanieidites speciosus, n. sp.
Aquilapollenites amplus Stanley
Aquilapollenites delicatus Stanley
Aquilapollenites murus Stanley
Aquilapollenites pulvinus Stanley
Aquilapollenites reticulatus Stanley
Triapollis scabratus, n. sp.
Triatriopollenites pseudomagnificus, n. sp.
Wodehouseia spinata, Stanley

TABLE 14

POLLEN AND SPORES FOUND IN BOTH THE CROW BUTTE SECTION AND IN THE NORTH CAVE HILLS, TWIN BUTTE OR CANNONBALL SECTIONS

Sphagnum antiquasporites Wilson and Webster
Sphagnum australe (Cookson) Drozh.
Sphagnum australe parvum (Cookson), n. comb.
Hamulatisporis amplus, n. sp.
Cingulatisporites dakotaensis, n. sp.
Alsophilidites kerguelensis Cookson
Gleichenia circinidites Cookson
Cardioangulina diaphana (Wilson and Webster), n. comb.
Osmunda comaumensis (Cookson), n. comb.
Laevigatosporites haardti (Pot. and Ven.) Thom. & Pf.
Laevigatosporites ovatus Wilson and Webster
Leiotrilletes pseudomaximus (Pf. and Thom.), n. comb.
Azolla cretacea, n. sp.
Triplanosporites sinuosus Pflug
Thuja ? hiatus (Potonie), n. comb.
Ephedra voluta, n. sp.
Rhoipites pisinnus, n. sp.
Pachysandra cretacea, n. sp.
Pseudotricolpites reticulatus, n. sp.

TABLE 15

NUMBER AND PERCENTAGES OF SPECIES OF SPORES AND POLLEN RESTRICTED AND COMMON TO THE SECTIONS STUDIED

	No.	%
Spore and Pollen Species restricted to North Cave Hills, Twin Butte, or Cannonball sections	33	41
Spore and Pollen Species restricted to the Crow Butte section	27	34
Spore and Pollen Species Common to the North Cave Hills, Twin Butte or Cannonball sections and the Crow Butte section	20	25

in all sections (Table 14), and these species are thought to have little stratigraphic significance but may be good ecological indicators.

The above data lend support to the interpretation that no part of the Twin Butte section is correlatable with the Crow Butte section and is approximately the same age as the lower part of Zone I of the North Cave Hills section. If the North Cave Hills section is lower Paleocene and the Crow Butte section late Upper Cretaceous, then the Twin Butte section, in its entirety, must also be of early Paleocene age.

CANNONBALL SECTION

Plant microfossils.—At this time there appears to be little doubt about the age of the Cannonball member of the Fort Union formation. Fox and Ross (1940), Brown (1938, 1962), Jeletsky (1960), and others have presented sufficient data so there is no need for a detailed discussion on this point. The plant microfossil distribution (Table 6) shows that many species restricted to the North Cave Hills and Twin Butte sections (Table 12) are also present in the Cannonball section. On the other hand, none of the species restricted to the Crow Butte section (Table 13) occurs in the Cannonball section. If the North Cave Hills and Twin Butte sections are early Paleocene, then the Cannonball section is of the same age.

Dinoflagellates and hystrichosphaerids.—Although the age of the Cannonball member is fairly well established, it was thought that the Paleocene age of this unit could be corroborated from a separate line of evidence, namely, the hystrichosphaerids and dinoflagellates. Because only previously described species could be used for this attempt, a limited number of species was available. These species are listed in Table 16.

TABLE 16
DINOFLAGELLATES AND HYSTRICHOSPHAERIDS USED
FOR DATING

SPECIES	OCCURRENCE AGE
<i>Deflandrea speciosa</i> Alberti	Europe, Paleocene
<i>Gymnodinium nelsonense</i> Cookson	Australia, U. Cretaceous
<i>Paleocystodinium golzowense</i> Alberti	Europe, Eocene
<i>Areoligera</i> aff. <i>A. senonensis</i> Lejeune-Carpentier	Europe, U. Cretaceous
<i>Hystrichosphaeridium colligerum</i> Defl. & Cook	Australia, Eocene
<i>Hystrichosphaeridium inodes</i> Klumpp	Europe, Eocene-Miocene
<i>Hystrichosphaeridium tubiferum</i> (Ehrb.) Defl.	Europe, U. Cret.-Miocene
<i>Michrhystridium piliferum</i> Deflandre	Europe, U. Cretaceous
<i>Pterospermopsis australiensis</i> Defl. & Cook	Australia, L. Cretaceous

a) Dinoflagellates

Of the 11 species of dinoflagellates encountered in this investigation, only three were previously described and named.

Deflandrea speciosa Alberti was reported from the upper Paleocene sediments of Europe whereas *Palaeocystodinium golzowense* Alberti was found in the Eocene sediments of the same region. *Gymnodinium nelsonense* Cookson, to date, has been found to occur only in the Upper Cretaceous sediments of Australia.

Although two species of dinoflagellates are restricted to the early Tertiary and one species to the late Cretaceous, it is felt that the most one can say about the age of the Cannonball sediments based solely on the dinoflagellates is that it could be either late Cretaceous or very early Tertiary in age.

b) Hystrichosphaerids

Of the seven species of hystrichosphaerids described in this paper, only one is described as a new species. The other six species are individually discussed below with the hope of providing another, independent line of evidence for the age of the Cannonball member.

Aeroligera aff. *A. senonensis* is only compared with *A. senonensis* Lejune-Carpentier and, therefore, this species is excluded from this discussion.

Michrhystridium piliferum Deflandre is a species based on a single specimen and, consequently, is not considered a reliable indicator of a late Cretaceous age inasmuch as the range of the species is not known.

The occurrence of *Pterospermopsis australiensis* Deflandre and Cookson was originally described from the Lower Cretaceous sediments. Therefore its total range is also not known.

Hystrichosphaeridium tubiferum (Ehrb.) Deflandre has been reported from many localities in sediments ranging in age from Aptian (Eisenack, 1958) to Miocene (Gerlach, 1961). Its presence in the Cannonball sediments helps little to accurately date this stratigraphic unit.

Hystrichosphaeridium inodes Klumpp has been widely reported only from lower to about middle Tertiary sediments. Its

stratigraphic restriction appears to make it a good index species for the lower to middle Tertiary.

Hystrichosphaeridium colligerum Deflandre and Cookson has been reported from at least two localities, both early Tertiary in age. This species also is thought to be a good index fossil for the lower Tertiary.

Of the six previously described species of hystrichosphaerids recovered from the sediments of the Cannonball member, only two, *H. inodes* Klumpp and *H. colligerum* Deflandre and Cookson, are thought to be reliable indicators of a geologic age. It appears that the Cannonball member of the Fort Union formation is of lower to middle Tertiary and not of Cretaceous age.

c) Summary of Dinoflagellate and hystrichosphaerid evidence

Taking each group, the dinoflagellates and the hystrichosphaerids separately, it appears that with the limited number of species present, there is little to say about the age of the Cannonball member. If the data are integrated, a more precise age for this marine unit can be determined.

The possibilities for an age based on the hystrichosphaerid evidence range from lower to about middle Tertiary. The dinoflagellates support an age of either late Cretaceous or very early Tertiary for the Cannonball member. The only region of overlap in age of these two microfossil groups is the very early Tertiary and it is postulated that the Cannonball member of the Fort Union formation is Paleocene in age.

COMPARISON OF THE MICROFOSSILS WITH OTHER AREAS

PLANT MEGAFOSSILS

An attempt was made to correlate the data obtained from this study with those of other writers. The only related studies in the area are those of Dorf (1942) and Brown (1962). Unfortunately, these works deal only with plant megafossils. Nevertheless, the plant microfossils encountered in this study were compared with the publications of Dorf and Brown at the family level. Limited success was achieved in this attempt.

TABLE 17

DISTRIBUTION OF THE NUMBER OF SPECIES PER FAMILY OCCURRING IN THE CROW BUTTE SECTION AS OPPOSED TO THE NORTH CAVE HILLS, TWIN BUTTE OR CANNONBALL SECTIONS

	No. in Crow Butte	No. in Twin Butte etc.
Division Bryophyta		
Family Sphagnaceae	3	4
Division Tracheophyta		
Class Lycopodiineae		
Family Lycopodiaceae (PA)*	3	3
Family Selaginellaceae (PA)	1	2
Class Filicineae		
Family Dicksoniaceae (PA)	1	1
Family Gleicheniaceae	2	1
Family Gleicheniaceae (PA)	1	1
Family Hymenophyllaceae (PA)	0	1
Family Osmundaceae	1	1
Family Polypodiaceae (PA)	2	3
Family Salvinaceae	1	1
Family Schizaeaceae	2	2
Family Schizaeaceae (PA)	1	1
Incerta Familiae	4	1
Class Gymnospermae		
Family Cycadaceae (PA)	1	1
Family Cupressaceae	1	1
Family Pinaceae	1	2
Family Pinaceae (PA)	0	1
Family Podocarpaceae	0	1
Family Taxodiaceae	0	1
Family Ephedraceae	1	1
Class Angiospermae		
Family Anacardiaceae (PA)	2	2
Family Betulaceae	1	4
Family Buxaceae	1	1
Family Caprifoliaceae (PA)	0	1
Family Ericaceae	0	1
Family Haloragaceae	0	1
Family Juglandaceae	1	3
Family Olacaceae (PA)	1	0
Family Oleaceae (PA)	0	1
Family Proteaceae (PA)	1	0
Family Rosaceae (PA)	1	0
Family Sapindaceae (PA)	1	0
Family Vitaceae	1	1
Incerta Familiae	9	7

*Indicates that species are provisionally assigned to this family

Table 17 shows the number of species present in each family in both the Cretaceous section (Crow Butte) and the Tertiary

sections (Twin Butte, North Cave Hills, and the Cannonball section). In many cases, there appears to be little, or no difference in the total number of species present between the Cretaceous and Tertiary sections. This is reflected in Text-figure 3 which shows that the Ludlow member and the Hell Creek formation of this study have 62% of their families in common.

Only 9% of the families of the Hell Creek formation (based on plant microfossil evidence) are listed by Dorf from the Lance formation (based on plant megafossil evidence). A slightly better correlation was attained by comparing the plant microfossils from Ludlow with the Fort Union megafloora recently described by Brown. Low correlations were also obtained by comparing the plant families occurring in the Hell Creek formation of this study with Fort Union of Brown and also the Lance plant megafossils described by Dorf with this Ludlow study.

The comparisons show that, at least at the family level, there is a higher correlation between the plant microfossils of the Hell Creek formation and the Ludlow member than between any of the plant microfossils of this study and plant megafossils of the other two studies discussed. A possible explanation might be that Dorf's Lance Creek locality lies some 200 miles to the southwest. Perhaps there was enough difference in environmental conditions to permit a different type of plant assemblage.

The poor correlation between the Ludlow plant families of this study and the recent study of Brown was puzzling. Upon closer examination it was found that of the 500 collecting localities used by Brown in his study, only about 5 or 1% were in the state of South Dakota. It would be interesting to see the correlation one could obtain by sampling for plant microfossils at a plant megafossil locality.

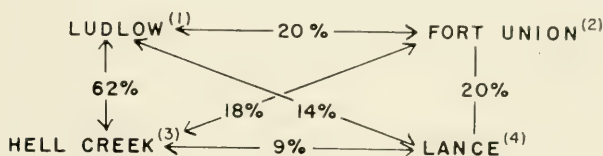
PLANT MICROFOSSILS

The only other published taxonomic study in the general area that deals with sediments of late Cretaceous and early Tertiary age is that of Anderson (1960). His data were based on six samples and are of limited value. Some interesting results are apparent from this study.

No species of *Aquilapollenites* Rouse is reported by Anderson.

TEXT-FIGURE 3

NUMBER OF PLANT FAMILIES IN COMMON WITH OTHER STUDIES



(1) PLANT MICROFOSSILS, THIS PAPER

(2) PLANT MEGAFOSSILS, BROWN, 1962

(3) PLANT MICROFOSSILS, THIS PAPER

(4) PLANT MEGAFOSSILS, DORF, 1942

The present writer has observed specimens of this genus as far south as Utah and this appears to be near the southern boundary of the genus. The northernmost representatives of the genus that the writer has personally seen are in the Anchorage area, southern Alaska. The genus appears to be wide spread in Siberia suggesting that the genus should be found north of the Anchorage region. The anomalous occurrence of *Aquilapollenites* (*Taurociphilus*) in western Scotland reported by Simpson (1961) is difficult to explain. The distribution of the genus as shown by Zaklinskaia (fig. 2, 1962) was thought to be more or less correct. However, in the light of Simpson's paper some modification of this distribution chart (Zaklinskaia, *op. cit.*) seems to be in order.

Proteacidites and *Engelhardtia* (*Momipites*) occur in both the South Dakota samples and also in Anderson's material. The species of *Engelhardtia* however, is thought to be different whereas the species of *Proteacidites* that occurs in the South Dakota Cretaceous is the same as described by Anderson. The distribution chart of Zaklinskaia (*op. cit.*) should also be modified to include overlap

in the distribution of *Aquilapollenites* and *Proteacidites*. This latter genus is found northward in the same areas as *Aquilapollenites*; although it doesn't appear to extend as far north to the area that Rouse (1957) sampled in western Canada. The southern limits of *Proteacidites* in North America reach further southward than does *Aquilapollenites*. Recently, the writer observed specimens of *Proteacidites* occurring in the late Cretaceous sediments of Delaware suggesting, again, a modification of Zaklinskaia's chart extending the range of this genus considerably eastward.

The appearance of representatives of the Bombacaceae in Anderson's area certainly suggest a tropical climate. This family has been reported from the Tertiary of Colombia (Sole de Porta, 1961), but to this writer's knowledge, it has not been found northward from Anderson's area.

The study by Rouse (1957) is of sediments that are slightly older than those of the South Dakota area discussed in this paper. There are many similarities, especially on the generic level with about one-third of the genera found in the Crow Butte section also being present in the western Canadian Upper Cretaceous.

As shown by Zaklinskaia (1962, fig. 2) and Pokrovskaja (1962), there appears to be a close resemblance in the Cretaceous-lower Tertiary spore and pollen assemblages between eastern North America and also between Siberia and the Northwestern Great Plains of the United States. The major work by Samoilovitch, (*et al.*, 1962) also shows this to be true. Mtchedlishvili and Samoilovitch (1962) pointed out that there is a close similarity between the Mesozoic-Cenozoic plant microfossil assemblages of Siberia and the extant flora of the Australian region. The same could be said for the plant microfossils of the Upper Cretaceous of the South Dakota area. Mtchedlishvili and Samoilovitch (*ibid.*) explained this similarity in the fossil and extant floras by postulating a northward and southward migration of species from some region intermediate to Siberia and Australia and concluded by stating (*op. cit.*, p. 104) "the lack of paleobotanical data from the Mesozoic of India and southeastern China does not permit as yet to localize this region more definitely." Inasmuch as the northern Great Plains of North America also has a similar assemblage, paleobotanical data from northern and central Africa,

as well as South America, might have an important bearing on the area of origin of this flora.

CLIMATIC AND ENVIRONMENTAL INTERPRETATIONS

Both Dorf (1942) and Brown (1962) made climatic interpretations based on the ratio of entire to nonentire fossil leaves and other features. Dorf (1942, p. 103) in his study of the Upper Cretaceous Lance megafloras concluded his discussion by stating that:

In summary it may be stated that the leaf characters and the distribution of the modern correlatives of the Lance species, as well as the absence or scarcity of typical cool temperate genera, point to humid lowland conditions of growth under a warm temperate to subtropical climate, more nearly approaching the former.

On the other hand, Brown in his monograph on the Paleocene plant megafossils stated (1962, p. 95):

A glance at the dicotyledonous leaves of the Paleocene flora shows that those with toothed margins far outnumber those with entire margins—a significant indication of adoption to a temperate climate.

The climatic interpretations by Dorf and Brown suggest that the temperature in the northwestern part of the Great Plains changed from warm temperate in the Upper Cretaceous to temperate in the Paleocene. An effort was made to see if the plant microfossil evidence would corroborate the megafossil evidence. Examination of Table 17 shows that many families that are present in the Crow Butte section (Upper Cretaceous) are also present in the Tertiary sections. For any sort of analysis of the two floras represented, one has to examine the plant fossils at least at the generic level.

The genera, that with some confidence are thought to be present, are listed in Table 18. They are subdivided into two categories depending on whether they are subtropical or temperate at the present. These data show that 10 of the extant genera that are found in the Tertiary sections are found today in temperate areas whereas only four of the genera found to occur in the Tertiary sections are at present found in subtropical areas. In the Upper Cretaceous section, only four genera are thought to be temperate and four other genera are thought to be subtropical. This low percentage of genera assignable to extant plant families is due, at least in part, to the

large percentage of archaic genera present in the Upper Cretaceous section and absent in the Tertiary sections. Because of the low number of genera assignable to either the subtropical or temperate group, one can say little about climatic conditions in the Late Cretaceous based on pollen and spore evidence presented.

TABLE 18
GENERA USED FOR CLIMATIC INTERPRETATIONS

PALEOCENE	
Subtropical genera	Temperate genera
<i>Gleichenia</i>	<i>Thuja</i>
<i>Azolla</i>	<i>Piceae</i>
<i>Anemia</i>	<i>Alnus</i>
<i>Schizaea</i>	<i>Betula</i>
	<i>Carpinus</i>
	<i>Myriophyllum</i>
	<i>Pachysandra</i>
	<i>Engelhardtia</i>
	<i>Pterocarya</i>
	<i>Vitis</i>
CRETACEOUS	
Subtropical genera	Temperate genera
<i>Gleichenia</i>	<i>Alnus</i>
<i>Azolla</i>	<i>Pterocarya</i>
<i>Anemia</i>	<i>Thuja</i>
<i>Schizaea</i>	<i>Pachysandra</i>

One interesting conclusion can be deduced from Table 18. Of the four genera present in the Cretaceous subtropical group, all are present in the Tertiary sections. If the temperate climatic interpretation is correct for the Paleocene sediments and if the subtropical climatic interpretation based on plant megafossils is correct for the Upper Cretaceous sediments, then one could conclude that the large number of subtropical elements present in the Paleocene are relicts.

Examination of the lithotypes in the area of investigation show that the Paleocene with its widespread lignites had a wet, humid climate. Certainly precipitation exceeded evaporation. The presence of certain upland forms in the lignitic sediments indicates the presence of an upland flora.

The absence of certain microfossils and the presence of certain other microfossils in the Cannonball section suggest some interesting interpretation of these data. All the samples from this section contain a large number of plant microfossils. Samples 18-2, 18-3 and

18-4 also contain a low percentage (usually less than 1%) of marine dinoflagellates. Their presence shows marine or perhaps brackish environmental conditions of deposition. Only sample 18-4 contains a low percentage (again about 1%) of hystrichosphaerids. The presence of this group of marine plankton shows that more marine conditions existed, at the location of the section, during the time of deposition of this sample. The absence of microforaminifers in any of the samples implies that no true marine conditions existed for the area of this section. Fox and Ross (1942) collected foraminifers from the Cannonball member at a locality some 100 miles to the east of the section sampled in this study. Interpretation of these data indicates that the Cannonball member sampled for this study represented the near-shore facies of the Cannonball Sea and that the main body of the sea lay eastward.

SUMMARY AND CONCLUSIONS

The four sections of Upper Cretaceous and lower Tertiary strata from northwestern South Dakota used in this investigation were measured, described, and sampled in approximately two weeks during the summer of 1956 and in two weeks during the summer of 1958. The four sections, in their combined thickness, represent 898.2 feet of strata. A total of 112 samples were collected, 65 of which contained plant microfossils whereas the remainder proved to be barren. The plant microfossils, and dinoflagellates and hystrichosphaerids are found to be assignable to 99 species represented by 64 genera; 60 species and 3 genera are described as new.

The Crow Butte section is divided into three zones which are based on "characteristic" species whereas the North Cave Hills section is divisible into two zones based on other "characteristic" species. Evidence is presented that there is no major "floral break" within the Cave Hills section, but that the plant microfossils present in the North Cave Hills section do differ markedly from those of the Crow Butte section. It is suggested that this difference is not the result of depositional environment but is a real stratigraphic difference. The plant microfossils throughout the North Cave Hills section have a decidedly modern aspect as contrasted to those pres-

ent in the Crow Butte section suggesting a major difference in composition in the floras represented by the fossil pollen and spores.

The Twin Butte section which is thought by some to contain the Cretaceous-Tertiary boundary has a plant microfossil assemblage that contains many of the diagnostic species of Zone I of the North Cave Hills section. No species that is "characteristic" of the Crow Butte section was found in the Twin Butte section.

The Cannonball member was found to contain a large number of fossil spores and pollen that were also restricted to the North Cave Hills section, and no species that was restricted to the Crow Butte section.

The data presented suggest the following conclusions:

1. The North Cave Hills section, in its entirety, is Paleocene inasmuch as some of the "characteristic" species that occur in this section have been reported only from Paleocene strata elsewhere.

2. The Crow Butte section is late Upper Cretaceous in age. The plant microfossil assemblage is markedly different from any of the European and Australian Upper Cretaceous assemblages and also from the North Cave Hills Paleocene section and most closely resembles the Upper Cretaceous assemblage described by Samoilovitch, *et al.*, from western Siberia.

3. The Twin Butte section does not contain the Cretaceous-Tertiary boundary but is correlative with Zone I of the North Cave Hills section.

4. The Cannonball section is divisible into three zones with the central marine to brackish part referred to the Cannonball member whereas the upper and lower nonmarine zones are assignable to the Ludlow member. The age of the Cannonball member is independently corroborated on both plant microfossil and dinoflagellate-hystrichosphaerid evidence as assignable to the Paleocene.

5. Climatic interpretations based on the fossil pollen and spores suggest a temperate climate for the South Dakota area during Paleocene time.

This investigation has, in reality, just "scratched the surface" of the wealth of plant microfossil material available in the Upper Cretaceous and lower Tertiary strata of the Great Plains region

of the Western United States. Some of the stratigraphic ranges of the species herein described will undoubtedly be extended. It is hoped that when this additional information becomes available it will be published so that the interested workers can interpret better the evolution and distribution of plants through geologic time.

SYSTEMATIC PALYNOLOGY

DIVISION PYRRHOPHYTA

Family **DEFLANDREIDAE** Eisenack, 1954

Genus **DEFLANDREA** Eisenack, 1938

Deflandrea Eisenack, 1938, Schr. Physik.-ökon. Ges. Königsberg, vol. 70, p. 187.

Deflandrea Eisenack, *Deflandrea* in Piveteau, 1952, *Traité de Paléontologie*, vol. 1, p. 118.

Deflandrea Eisenack, Eisenack, 1954, *Palaeontographica*, pt. A, vol. 105, p. 52.

Deflandrea Eisenack, Alberti, 1959, *Mitt. Geol. Staatssinat.*, pt. 28, p. 94.

Deflandrea Eisenack, Gerlach, 1961, *Neues Jb. Geol. Palaeont.*, vol. 112, No. 2, p. 150.

Deflandrea Eisenack, Eisenack, 1961, *Neues Jb. Geol. Palaeont.*, vol. 112, No. 3, p. 305.

Type species.—*Deflandrea phosphoritica* Eisenack, 1938.

Description.—Cell encapsulated usually anterior-posteriorly elongated and dorso-ventrally flattened; one apical horn and two antapical horns present. Girdle and furrow distinct to indistinct; pylome usually present.

Distribution.—After Alberti, 1961 (p. 42) the stratigraphic range of *Deflandrea* in Europe and Australia is from Lower Cretaceous to lower Tertiary.

Deflandrea dakotaensis Stanley, n. sp.

Pl. 19, figs. 1-3

Holotype.—Slide 18-3-5; location 27.4 $\times$ 92.5; Pl. 19, figs. 1-3

Type locality.—Southern half of sec. 24 T. 23 N., R. 9 E., Harding Co., South Dakota.

Type horizon.—Cannonball member, Fort Union formation. Paleocene.

Name derivation.—Dakota; after the state of South Dakota.

Description.—Outer cyst distinctly anterior-posteriorly elongated with a bulge in the equatorial region and dorso-ventrally flattened; length about 120 μ , width approximately 84 μ ; membrane smooth, approximately 1 μ thick in anterior portion of outer cyst and thins to a fraction of a micron posteriorly. Apical horn about

25 μ in length and terminated with a small, solid papilla. Antapical horns approximately equal in size with the left one slightly longer than the right horn; antapical horns connected to each other by a membrane. Interior cyst anterior-posteriorly flattened, granular. Furrow and girdle not observed. Intercalary archeopyle distinct with posterior side longer than anterior side.

Differential diagnosis.—*Deflandrea dakotaensis*, n. sp. resembles *D. bakeri* Deflandre and Cookson and *D. pellucida* Cookson and Eisenack. It differs from those species in that the cell membrane is smooth and there is no or only a faint suggestion of a girdle. It differs from *D. phosphoritica* Eisenack in that the posterior region is much longer. Also, *D. dakotaensis* lacks the girdle and the furrow of *D. phosphoritica* (as recently discussed in the fine paper of Manum, 1960).

Occurrence.—*Deflandrea dakotaensis*, n. sp. was found to be limited to sample 18-3 of the Cannonball member.

Frequency.—"Infrequent."

Deflandrea magnifica Stanley, n. sp.

Pl. 20, figs. 1-6

Holotype.—Slide 18-4-7; location 24.6 $\times$ 100.6; Pl. 20, figs. 4-6.

Isotype.—Slide 18-4-11; location 40.4 $\times$ 100.3; Pl. 20, figs. 1-3.

Type locality.—Southern half of sec. 24, T. 23 N., R. 9 E., Harding Co., South Dakota.

Type horizon.—Cannonball member, Fort Union formation, Paleocene.

Name derivation.—*Magnificus* = splendid; named after the large splendid nature of specimens of this species.

Description.—Outer cyst large, pentagonal in dorso-ventral view; length 120-135 μ overall; width 100-115 μ ; outer cyst wall smooth to covered with small irregularly placed spines; wall thin and often longitudinally wrinkled. Apical horn 5-10 μ long; antapical horns about 5-10 μ in length with left horn slightly longer than the right one; antapical horns tend to slightly diverge from each other. Inner cyst completely fills the outer one. Girdle well developed, width about 8 μ . Furrow about 15 μ wide and is bordered by a more or less frilled border. Archeopyle six-sided with posterior side considerably longer than the anterior one.

Differential diagnosis.—*Deflandrea magnifica*, n. sp. is differentiated from *D. pannucea*, n. sp. by its distinctly larger size and its shorter antapical horns.

Occurrence.—*Deflandrea magnifica*, n. sp. was found to occur only in sample 18-4 of the Cannonball member.

Frequency.—"Infrequent."

***Deflandrea microgranulata* Stanley, n. sp.**

Pl. 19, figs. 4-6

Holotype.—Slide 18-4-11; location 43.7×112.7 ; Pl. 19, figs. 4-5.

Isotype.—Slide 18-4-2; location 31.9×101.0 ; Pl. 19, fig. 6.

Type locality.—Southern half of sec. 24, T. 23 N., R. 9 E., Harding Co., South Dakota.

Type horizon.—Cannonball member, Fort Union formation, Paleocene.

Name derivation.—Named after the microgranulations on the inner cyst.

Description.—Outer cyst subcircular in dorso-ventral view; length $54-57 \mu$, width $45-48 \mu$; outer cyst wall smooth and thin. Apical horn conically shaped, length about 7μ ; apical horn appears to bear a pore at its distal end. Antapical horns unequal in length with left one being short (about 5μ in length), whereas the right one is only slightly developed. Inner cyst completely fills outer cyst, pentagonally shaped with the posterior end flattened; small granulations with a diameter of about 0.3μ ornament the membrane of the inner cyst. Girdle characterized by a wide band that is well developed on the dorsal side and blends into the furrow on the ventral side. Archeopyle often distinct with the anterior and posterior sides being about equal in length.

Differential diagnosis.—*Deflandrea microgranulata*, n. sp. closely resembles *D. ventrisoa* Alberti, 1959. The only difference that could be determined from Alberti's description and illustration is that *D. microgranulata* has a slightly smaller size and the apical horn bears a distal pore. It may well be that *D. microgranulata* will have to be put into synonymy at a later date. At present it is thought best to keep them separate.

Occurrence.—*Deflandrea microgranulata*, n. sp. was found to be restricted to sample 18-4 of the Cannonball member.

Frequency.—"Infrequent."

Deflandrea pannucea Stanley, n. sp.

Pl. 22, figs. 1-4, 8-10

Holotype.—Slide 18-4-11; location 23.6×108.5 ; Pl. 22, figs. 3-4.*Isotype*.—Slide 18-4-5; location 27.4×102.2 ; Pl. 22, figs. 1-2.*Type locality*.—Southern half of sec. 24, T. 23 N., R. 9 E., Harding Co., South Dakota.*Type horizon*.—Cannonball member, Fort Union formation; Paleocene.*Name derivation*.—*Pannuceus*=wrinkled; after the characteristic wrinkled nature of the outer cyst membrane.*Description*.—Outer cyst more or less pentagonal in dorso-ventral view; length 80-100 μ , width 55-78 μ ; outer cyst membrane smooth, thin and characteristically longitudinally wrinkled. Apical horn 15 μ in length, hollow with what appears to be a distal pore present. Antapical horns typically divergent, length of horns about 25 μ with left horn always slightly longer than the right one. Interior cyst large, commonly subpentagonally shaped with the posterior end flattened; interior cyst more or less completely fills the outer cyst. Girdle distinct and well developed whereas furrow is usually indistinct. Archeopyle distinct to indistinct with the length of the posterior side approximately equaling that of the anterior side.*Differential diagnosis*.—*Deflandrea pannucea*, n. sp. somewhat resembles *D. obliquipes* Deflandre and Cookson with its diverging antapical horns and the subpentagonal inner cyst filling the outer one. It differs from this species of Deflandre and Cookson in that it is slightly smaller in size and, more importantly, has a smooth outer cyst membrane that is not longitudinally wrinkled.*Occurrence*.—*Deflandrea pannucea*, n. sp. was found to occur in samples 18-3 and 18-4 of the Cannonball member.*Frequency*.—"Infrequent."**Deflandrea speciosa** Alberti, 1959

Pl. 19, figs. 7-9

Deflandrea speciosa Alberti, 1959, Mitt. Geol. Staatsinst., vol. 28, p. 97, pl. 9, figs. 12-13.*Holotype*.—Preparation No. Gor/p 1, pl. 9, fig. 13, Alberti, 1959.*Description*.—Outer cyst more or less pentagonal in dorso-ventral view; length 96 μ , width 64 μ ; outer cyst membrane thin-walled,

covered with irregularly spaced tubercles that have a height of less than $1\ \mu$. Apical horn long, conical-shaped; antapical horns about equal in length with the left one being slightly longer than the right horn; horns moderate in length and slightly divergent. Inner cyst thin-walled, smooth and circular in outline. Girdle distinct and well developed on dorsal side; on ventral side the girdle is interrupted and blends into a more or less indistinct, wide furrow. Archeopyle distinct with both the anterior and posterior sides being about equal in length.

Discussion.—The specimens described herein agree closely with those described by Alberti with the exception of the size. The Cannonball specimens average about $15\ \mu$ less in size.

Occurrence.—*Deflandrea speciosa* Alberti was found to occur only in sample 18-3 of the Cannonball member (Paleocene) of South Dakota. The only other presently known occurrence of this species is from the upper Paleocene of Germany (Alberti, 1959).

Frequency.—"Infrequent."

Genus **WETZELIELLA** Eisenack, 1938

Wetzelicella Eisenack, 1938, Schr. Physik.-ökon. Ges. Königsberg, vol. 70, p. 186.

Wetzelicella Eisenack, Deflandre, 1952, in Piveteau, *Traité de Paléontologie*, vol. 1, p. 118.

Wetzelicella Eisenack, Gocht, 1952, *Sonder. Zeit. Geol.*, vol. 1, No. 4, p. 314.

Wetzelicella Eisenack, Eisenack, 1954, *Palaeontographica*, pt. A, vol. 105, p. 54.

Wetzelicella Eisenack, Gerlach, 1961, *Neues Jb. Geol. Paleont.*, vol. 112, No. 2, p. 152.

Wetzelicella Eisenack, Eisenack, 1961, *Neues Jb. Geol. Paleont.*, vol. 112, No. 3, p. 305.

Type species.—*Wetzelicella articulata* Eisenack, 1938.

Description.—Dorso-ventrally flattened cysts with a more or less rhomboidal outline. Apical horn and two antapical horns present with a tendency of one of the antapical horns to be reduced in size. Outer cyst membrane usually bears spinelike processes. Inner cyst more or less completely fills the outer cyst. Girdle poorly to more or less well developed.

Distribution.—*Wetzelicella* is common in the lower Tertiary sediments in Europe. Cookson and Eisenack, however, have assigned at least one species from the upper Jurassic sediments of Western Australia to this genus.

Wetziella pilata Stanley, n. sp.

Pl. 21, figs. 12-16

Holotype.—Slide 18-3-2; location 43.4×108.5 ; Pl. 21, figs. 14-16.

Isotype.—Slide 18-3-4; location 40.4×91.7 ; Pl. 21, figs. 12, 13.

Type locality.—Southern half of sec. 24, T. 23 N., R. 9 E., Harding Co., South Dakota.

Type horizon.—Cannonball member, Fort Union formation, Paleocene.

Name derivation.—*Pila*=ball; after the ball-like expansion of the distal end of the sculpture elements.

Description.—Outer cyst more or less pyriform to rhomboidal in dorso-ventral view; length $42-49 \mu$, width about 30μ . Hypotheca smaller than epitheca. Outer cyst membrane thin, moderately folded; membrane ornamented with rodlike elements that usually have a small ball-like expansion on the distal end (*pila*); length of spines 1.5 to 3μ . Apical horn about 5μ long. Left antapical horn approximately 9μ long whereas the right antapical horn is usually not developed. Girdle on the order of 5μ wide and more or less distinct; furrow and archeopyle indistinct.

Differential diagnosis.—*Wetziella pilata*, n. sp. differs from *W. rugosa*, n. sp. by having long sculpture elements that are expanded at their distal end.

Occurrence.—This new species was found to be restricted to samples 18-2 and 18-3 of the Cannonball member.

Frequency.—"Infrequent."

Wetziella rugosa Stanley, n. sp.

Pl. 21, figs. 6-11

Holotype.—Slide 18-3-2; location 32.1×95.8 ; Pl. 21, figs. 10-11.

Isotype.—Slide 18-3-3; location 38.4×107.5 ; Pl. 21, figs. 7-8.

Type locality.—Southern half of sec. 24, T. 23 N., R. 9 E., Harding Co., South Dakota.

Type horizon.—Cannonball member, Fort Union formation; Paleocene.

Name derivation.—*Rugosa*=wrinkled; after the characteristic wrinkled nature of specimens of this species.

Description.—Outer cyst rhomboidal to subrhomboidal in outline with the length being either slightly longer or slightly shorter

than the width. Length varies between 50-60 μ whereas the width also varies between 50-60 μ . Outer cyst membrane thin and almost always irregularly folded or crumpled; membrane bears spinelike sculpture elements that have a length of about 1.5 to 2 μ . Apical horn about 3-5 μ in length; antapical horns two in number; the left one being well developed with a length of about 5 μ whereas the right one is poorly developed. Girdle indistinct but does appear to be bordered on both edges by a row of spinelike processes. Interior cyst thin-walled and more or less completely fills the outer cyst.

Differential diagnosis.—*Wetzeliiella rugosa*, n. sp. is differentiated from *W. pilata*, n. sp. by its spinelike sculpture elements that lack any expansion at their distal ends.

Occurrence.—*Wetzeliiella rugosa*, n. sp. was found to be restricted to samples 18-2 and 18-3 of the Cannonball member.

Frequency.—"Infrequent."

Family GYMNODINIDAE Bergh

Genus **GYMNODINIUM** Stein emended Kofoid and Swezy, 1921

Gymnodinium Stein, 1883, *Die Organismus der Infusionstiere* III, pt. 2, *Die Naturgeschichte der Arthrodelen Flagellaten*, p. ?.

Gymnodinium Stein emended Kofoid and Swezy, 1921, *Mem. Univ. Calif.*, vol. 5, p. 158.

Gymnodinium Stein emended Kofoid and Swezy. Lebour, 1925, *Dinoflagellates of Northern Seas*, p. 34.

Gymnodinium Stein, Schiller, 1933, in Rabenhorst's *Kryptogamen Flora*, *Dinoflagellatae*, p. 322.

Gymnodinium Stein, Chatton, 1952, in Grassé, *Traité de Zoologie*, vol. 1, p. 331.

Gymnodinium Stein, Deflandre, 1952, in Piveteau, *Traité de Paléontologie*, p. 118.

Type species—??

Description.—Cyst usually anterior-posteriorly elongated; girdle complete and not displaced or displaced left-handedly. Membrane smooth or anterior-posteriorly striated; furrow usually present.

Distribution.—The range of the genus *Gymnodinium*, after Deflandre, 1952, is from Jurassic to Recent.

Gymnodinium nelsonense Cookson, 1956

Pl. 22, fig. 7

Gymnodinium nelsonense Cookson, 1956, *Australian Jour. Marine and Freshwater Res.*, vol. 7, No. 1, p. 183, pl. 1, figs. 8-11.

Gymnodinium nelsonense Cookson, Cookson and Eisenack, 1958, *Roy. Soc. Victoria*, vol. 70, pt. 1, p. 26, pl. 1, fig. 8.

Holotype.—Illustrated plate 1, figure 10, Cookson, 1956.

Description.—Cyst more or less fusiform; length 57 μ , width 27 μ . Membrane appears to be finely granulate, longitudinally wrinkled or striated and thin-walled; thickness of membrane on order of 0.5 μ . Girdle divides cell into two unequal portions with a shorter epitheca and a longer hypotheca. Apex broadly rounded whereas hypotheca narrows distally toward a bluntly pointed antapex. Girdle distinct but because of the wrinkled nature of the specimens, it is not determinable whether or not any displacement is present. Furrow is more or less indistinct. Archeopyle usually large and circular to subcircular.

Discussion.—The specimens described herein are somewhat smaller than the specimen Cookson described from Australia. They agree in all other respects, and, therefore, it is felt that subspeciation is not warranted.

Occurrence.—*Gymnodinium nelsonense* Cookson was found to be restricted to sample 18-3 from the Cannonball member. Cookson and Eisenack, 1957, stated that the range of the species is from Campanian to Lower Maestrichtian. The occurrence of this species in the Cannonball member would extend the range into the Paleocene.

Frequency.—"Infrequent."

INCERTAE FAMILIAE

Genus **PALAEOCYSTODINIUM** Alberti, 1961

Palaeocystodinium Alberti, 1961, *Palaeontographica*, pt. A, vol. 116, p. 20.

Type species.—*Palaeocystodinium golzowense* Alberti, 1961.

Description.—Fusiform cells with both ends drawn out into spinelike processes. Inner cyst fusiform, more or less confined to outer cyst proper and does not extend to any great degree into the spinelike processes of the outer cyst. A hexagonal intercalary archeopyle is present.

Distribution.—Of the two species described and assigned to this genus by Alberti one is confined to the Oligocene, whereas the other is restricted to Upper Cretaceous sediments. The occurrence of the Paleocene species below does not alter the range of the genus.

Palaeocystodinium golzowense Alberti, 1961

Pl. 23, figs. 1-2

Palaeocystodinium golzowense Alberti, 1961, *Palaeontographica*, pt. A., vol. 116, p. 20, pl. 7, figs. 10-12; pl. 12, fig. 16.

Holotype.—Preparation No. A-17; pl. 7, fig. 9, Alberti, 1961.

Description.—Outer cyst fusiform with little or no dorso-ventral flattening; cell width 30-54 μ . Inner cyst more or less fusiform; length 60-120 μ ; width 21-48 μ . A hexagonally shaped archeopyle is present on the cell.

Discussion.—No specimen was observed that was completely intact so that it was impossible to measure the overall length of a complete specimen. However, the length and width of the inner cyst and the width of the outer cyst were measurable and indicate that the variation of the South Dakota specimens is slightly greater than that of the specimens described by Alberti. These size variations tend to slightly straddle the ranges given by Alberti for the species and, therefore, the South Dakota specimens are justifiably assignable to *Palaeocystodinium golzowense*.

Occurrence.—The specimens described by Alberti were from upper Eocene and middle and upper Oligocene sediments of Germany. The occurrence of this species in the Paleocene sediments of South Dakota slightly extends the biorange of the species. *Paleocystodinium golzowense* Alberti was found to occur only in sample 18-4 of the Cannonball member (Paleocene) of South Dakota.

Frequency.—"Infrequent."

Genus SPINIDINIUM Cookson and Eisenack, 1962

Spinidinium Cookson and Eisenack, 1962, *Micropaleontology*, vol. 8, No. 4, p. 489.

Type species.—*Spinidinium styloniferum* Cookson and Eisenack, 1962.

Description.—Outer cyst anterior-posteriorly elongated, dorso-ventrally flattened with more or less convex sides. Cyst membrane ornamented with small spinelike elements; inner cyst present; girdle and furrow more or less well developed; tabulation absent.

Discussion.—The original description of Cookson and Eisenack, 1962 is vague inasmuch as no mention is made as to how this species differs from *Deflandrea* or *Wetzeliella*. As far as can be made out from the original generic and the simple specific description and

also from the species herein assigned to *Spinidinium* the distinction is as follows.

Essentially *Spinidinium* is a *Deflandrea* type of dinoflagellate without the usually smooth outer cyst membrane of *Deflandrea* but is ornamented with spines. Cookson and Eisenack make no mention of an inner cyst but speak of a two-layered shell. From the description, and especially from the illustrations, it appears that a distinct inner cyst is present in their species of *Spinidinium styloniferum*. *Spinidinium* appears to differ from *Wetzeliella* by lacking the characteristic rhomboidal shape of this genus.

Distribution.—The species described and assigned to the genus *Spinidinium* by Cookson and Eisenack, 1962, was found in Albian-Aptian sediments. The occurrence of representatives of two new species of *Spinidinium* in the Paleocene sediments of the Cannonball member considerably extends the stratigraphic range of the genus.

***Spinidinium densispinatum* Stanley, n. sp.**

Pl. 21, figs. 1-5

Holotype.—Slide 18-4-11; location 41.3×104.7 ; Pl. 21, figs. 1-3.

Isotype.—Slide 18-2-2; location 34.5×107.2 ; Pl. 21, figs. 4-5.

Type locality.—Southern half of sec. 24, T. 23 N., R. 9 E., Harding Co., South Dakota.

Type horizon.—Cannonball member, Fort Union formation, Paleocene.

Name derivation.—*Densispinatum*=dense spines; named after the densely spinate cell.

Description.—Outer cyst subpentagonal in dorso-ventral view; length $50-65 \mu$, width $40-50 \mu$, epitheca larger than hypotheca. Outer cyst membrane thin and usually badly folded; ornamented with short rodlike, clublike, spinelike or grapple-like appendages that are about $2-3 \mu$ long. Apical horn short; conelike with a broad base and a distal pore (?); horn length $4-5 \mu$. Antapical horns two in number with the right one weakly developed whereas the left horn is well developed, but short; length of the latter horn is about $4-5 \mu$. Inner cyst thin-walled, more or less circular in outline and almost fills outer cyst. Often two nuclei-like bodies that are $7-8 \mu$ in diameter are present inside the inner cyst. Girdle distinct; girdle

border fringed by a row of spinelike appendages. Furrow wide, usually indistinct. Archeopyle, when present, usually polygonal in outline.

Differential diagnosis.—*Spinidinium densispinatum*, n. sp. is readily distinguished from *S. microceratum*, n. sp. by its more or less subcircular outline in dorso-ventral view and by its more densely spinate membrane. *Spinidinium densispinatum* differs from *S. styloniferum* Cookson and Eisenack by its shorter apical horn and by its subcircular outline dorso-ventral view.

Occurrence.—*Spinidinium densispinatum* was found to occur in both samples 18-2 and 18-4 from the Cannonball member.

Frequency.—"Infrequent."

Spinidinium microceratum Stanley, n. sp.

Pl. 22, figs. 5-6

Holotype.—Slide 18-2-1; location 27.8 $\times$ 91.8; Pl. 22, fig. 6.

Isotype.—Slide 18-2-1; location 27.5 $\times$ 92.2; Pl. 22, fig. 5.

Type locality.—Southern half of sec. 24, T. 23 N., R. 9 E., Harding Co., South Dakota.

Type horizon.—Cannonball member, Fort Union formation, Paleocene.

Name derivation.—*Microceratum*=small horn; named after the characteristic small apical horn.

Description.—Outer cyst subovaloid in dorso-ventral view; length 50-60 μ , width 32-43 μ ; membrane thin and badly folded, ornamented with short spinelike appendages that have a length of 1-1.5 μ . Apical horn short; antapical horns unequally developed with the right horn short whereas the left horn may have a length up to about 5 μ . Inner cyst thin walled and more or less completely fills outer cyst. Within the inner cyst of many specimens an elongated nuclei-like body is present. Girdle distinct, bordered by short spines, but girdle itself is usually free of spinelike ornamentation. Furrow indistinct. Archeopyle represented by a polygonally outline area on the epitheca.

Differential diagnosis.—*Spinidinium microceratum*, n. sp. is separated from *S. densispinatum*, n. sp. on its more or less oval outline in dorsoventral view and by its short apical horn. *Spinidinium microceratum* is readily distinguished from *S. styloniferum* Cookson and Eisenack by its considerably shorter apical horn.

Occurrence.—*Spinidinium microceratum*, n. sp. was found to occur only in sample 18-2 of the Cannonball member.

Frequency.—"Infrequent."

DIVISION PYRRHOPHYTA (?)

Family **HYSTRICHOSPHAERIDAE** O. Wetzel, 1938

Genus **AREOLIGERA** Lejeune-Carpentier, 1938

Arcoligera Lejeune-Carpentier, 1938, Ann. Soc. Géol. Belgique, p. 164.

Arcoligera Lejeune-Carpentier, W. Wetzel, 1952, Geol. Jb., vol. 66, p. 396.

Type species.—*Arcoligera senonensis* Lejeune-Carpentier, 1938.

Description.—Cysts with a subspherical shape; one pole is more or less flattened whereas the opposite pole is convex. Appendages simple to complex processes arranged into fields. The convex pole usually bears the complex processes whereas the opposite, flattened pole supports simpler, less complex processes.

Distribution.—The species described by Lejeune-Carpentier and W. Wetzel and assigned to *Arcoligera* have thus far been restricted to sediments of Upper Cretaceous and Danian age.

Arcoligera* aff. *A. senonensis Lejeune-Carpentier Pl. 26, figs. 1-8

Arcoligera senonensis Lejeune-Carpentier, 1938, Ann. Soc. Géol. Belgique, p. 164, figs. 1-3.

Arcoligera senonensis Lejeune-Carpentier, W. Wetzel, 1952, Geol. Jb., vol. 66, p. 396, fig. 6.

Description.—Cyst subspherical with a diameter of 45-55 μ . A flattened or depressed polar area bears perforated collar-like processes that are 15-25 μ long whereas the opposite polar area is encircled by processes that are about 6-12 μ long and have their bases fused and distal ends free. The equatorial area is bordered by rings or fields of processes. Cyst membrane 1 μ thick and distinctly granular.

Discussion.—The generic description given by Lejeune-Carpentier clearly indicated that the convex pole bears the longer more complex appendages whereas the flattened pole supports the shorter appendages. In the species described above, just the opposite is true. In most other respects this species closely resembles those presently assigned to *Arcoligera*. One solution to the problem would be to erect a new genus for the above described species. The other alternative and the one followed here is to temporarily assign this species

and compare it with a previously described species. The species is compared with (*affinis*; having affinity with but not identical with; Schenk and McMasters, 1948, p. 27) *Areoligera senonensis* Lejeune-Carpentier.

Differential diagnosis.—The species herein assigned to *Areoligera* differs from those assigned to *Chiropteridium* Gocht by having distinct fields. On the other hand, species assigned to *Systematophora* Klement also have fields, but the processes are markedly different than those of *Areoligera*.

Occurrence.—In the South Dakota area the above described species was found to occur in sample 18-4 of the Cannonball member of the Fort Union formation.

Frequency.—"Infrequent."

Genus **CYCLONEPHELIUM** Deflandre and Cookson emended Cookson and Eisenack, 1962

Cyclonephelium Deflandre and Cookson, 1955, Australian Jour. Marine Freshwater Res., vol. 6, No. 2, p. 285.

Cyclonephelium Deflandre and Cookson emended Cookson and Eisenack, 1962, Micropaleont., vol. 8, No. 4, p. 493.

Type species.—*Cyclonephelium compactum* Deflandre and Cookson, 1955.

Description.—Flattened cysts that are ovaloid in outline with a more or less distinct bilateral symmetry. Ornamentation variable but always limited to the peripheral or equatorial region of the shell. One end of the bilaterally symmetrical cyst, the apical, is often open due to the detachment of this region (archeopyle). The opposite end, the antapical, according to Cookson and Eisenack, 1962, sometimes bears ornamentation that is more strongly developed.

Distribution.—The two species described by Deflandre and Cookson, 1955, and the four new species described by Cookson and Eisenack, 1962, are all limited to the Cretaceous. The new species described below is the first representative of this genus from Paleocene strata.

Cyclonephelium lemniscatum Stanley, n. sp.

Pl. 24, figs. 1-6

Holotype.—Slide 18-4-17; location 31.0 $\times$ 97.8; Pl. 24, figs. 1-2.

Isotype.—Slide 18-4-11; location 41.0 $\times$ 99.6; Pl. 24, figs 3-4.

Type locality.—Southern half of sec. 24, T. 23 N., R. 9 E., Harding Co., South Dakota.

Type horizon.—Cannonball member, Fort Union formation, Paleocene.

Name derivation.—*Lemniscus*=ribbon; named after the ribbon-like ornamentation characteristic of this species.

Description.—Cyst flattened, outline in polar view circular with sculptured elements distributed in equatorial region; diameter 68–79 μ . Cyst wall approximately 0.5 μ thick, surface of shell finely pitted with lumina under 0.5 μ in diameter. Sculpture elements consist of ribbon-like to threadlike elements that are fused with adjacent elements in their central region leaving both the distal and proximal ends free; length of elements about 25 μ . A more or less distinct opening may be present by the detachment of one end of the cyst (the apical archeopyle).

Differential diagnosis.—The moderately long ribbon-like sculpture elements readily distinguish *Cyclonephelium lemniscatum*, n. sp. from other previously described species.

Occurrence.—*Cyclonephelium lemniscatum*, n. sp. was found to occur in samples 18-2 and 18-4 from the Cannonball formation.

Frequency.—"Infrequent."

Genus **HYSTRICHOSPHAERIDIUM** Deflandre emended Eisenack, 1958

Hystrichosphaeridium Deflandre, 1937, Ann. Paleont., vol. 26, p. 20.

Hystrichosphaeridium Deflandre, Pastiels, 1948, Mus. d'Hist. Nat. de Belgique, Mem., No. 109, p. 37.

Hystrichosphaeridium Deflandre, Klumpp, 1953, Palaeontographica, pt. A, vol. 103, p. 390.

Hystrichosphaeridium Deflandre, Deflandre in Piveteau, 1952, Traité de Paléontologie, p. 325.

Hystrichosphaeridium Deflandre, Valensi, 1953, Mem. Soc. Geol. Français, n.s., vol. 32, No. 68, p. 35.

Hystrichosphaeridium Deflandre, Eisenack, 1954, Palaeontographica, pt. A, vol. 105, p. 65.

Hystrichosphaeridium Deflandre emended Eisenack, 1958, Neues Jb. Geol. Palaeont., vol. 106, p. 399.

Hystrichosphaeridium Deflandre emended Eisenack, Gerlach, 1961, Neues Jb. Geol. Palaeont., vol. 112, p. 184.

Type species.—*Hystrichosphaeridium tubiferum* (Ehrenberg) Deflandre, 1937.

Description.—Shell more or less spherical, not divided into fields. Appendages hollow, trumpet-like with the distal end considerably broader than the proximal end.

Hystrichosphaeridium colligerum Deflandre and Cookson, 1955

Pl. 24, figs. 7-8

Hystrichosphaeridium sp. C Cookson, 1953, Nat. Mus. Melbourne, Mem., vol. 18, pl. 2, figs. 29, 30.

Hystrichosphaeridium colligerum Deflandre and Cookson, 1955, Australian Jour. Marine and Freshwater Res., vol. 6, No. 2, p. 278, pl. 7, fig. 3.

Hystrichosphaeridium colligerum Deflandre and Cookson, Cookson and Eisenack, 1961, Roy. Soc. Western Australia, vol. 44, pt. 2, p. 44, pl. 2, fig. 9.

Description.—Cyst globular, bilaterally symmetrical; size of the single observed specimen $24.0 \times 27.0 \mu$; membrane about 1μ thick, finely granular. Processes 10-12 μ long, 1.5μ wide at base and taper to a narrow blunt distal end. At one pole a collar-like outgrowth with dimensions of $9 \times 12 \mu$ is present; the distal end of this polar collar is open. This opening may be the result of tearing of the distal end of the collar.

Discussion.—Cookson, 1953, illustrated one specimen of a species which may be assignable to *Hystrichosphaeridium colligerum* Deflandre and Cookson. Although Cookson did not describe this specimen, she did state that it came from a questionable Oligocene locality. The specimens described by Deflandre and Cookson, 1955, and Cookson and Eisenack, 1961 are from a locality that is thought to be lower Eocene in age. The single specimen herein described, although somewhat smaller than the specimens described by the authors of the species does fit it in every other respect and extends the lower end of the range into the Paleocene.

Occurrence.—The single illustrated and described specimen was found to occur in sample 18-4 of the Cannonball member, Fort Union formation.

Frequency.—"Infrequent."

Hystrichosphaeridium inodes Klumpp, 1953

Pl. 25, figs. 1-6

Hystrichosphaeridium inodes Klumpp, 1953, Palaeontographica, pt. A, vol. 103, p. 391, pl. 18, figs. 1, 2.

Hystrichosphaeridium inodes Klumpp, Deflandre and Cookson, 1955, Australian Jour. Marine Freshwater Res., vol. 6, No. 2, p. 277; pl. 8, fig. 7.

Hystrichosphaeridium inodes Klumpp, Gerlach, Neues Jb. Geol. Palaeont., vol. 112, p. 186, pl. 28, figs. 4 & 5.

Holotype.—Preparation W 622a, Klumpp, 1953

Description.—Cyst more or less spherical, diameter 65-75 μ ; cyst membrane distinctly two-layered with a thin outer membrane

forming the trumpet-shaped processes and a 1.5-2 μ inner supporting layer. Length of processes 22-27 μ . A polygonal archeopyle is present.

Occurrence.—*Hystrichosphaeridium inodes* Klumpp was found to be restricted to sample 18-4 of the Cannonball member, Fort Union formation.

Frequency.—"Infrequent."

Hystrichosphaeridium tubiferum (Ehrb.) Deflandre Pl. 25, figs. 7-12

Xanthidium tubiferum Ehrenberg, 1838, Abhand. K. Akad. Wiss., Berlin, pl. 1, fig. 16.

Hystrichosphaera tubifera O. Wetzel, 1933, Palaeontographica, pt. A, vol. 78, p. 40, pl. IV, fig. 16.

Hystrichosphaeridium tubiferum (Ehrb.), Deflandre, 1937, Ann. Pal., vol. 26, p. 21.

Hystrichosphaeridium tubiferum Deflandre, Lejeune-Carpentier, 1939, Ann. Soc. Géol. Belgique, vol. 63, p. 218.

Hystrichosphaeridium tubiferum Deflandre, Eisenack, 1958, Neues Jb. Geol. Palaeont., vol. 106, p. 401.

Pleisiotypes.—AJ98; AF77, AJ65, Deflandre, 1937.

Description.—Cyst more or less spherical; diameter 32-40 μ . Membrane two layered, consisting of a thin outer layer and a thicker inner layer. The processes number about 25; they are 15-20 μ long, hollow, and are flared at both the distal and proximal ends with the distal end being broader than the proximal and the central portion being the narrowest. In one region of the shell (the distal?) there are several thinner processes present. An archeopyle is usually present in the area 90° away from the region that bears the smaller processes.

Occurrence.—*Hystrichosphaeridium tubiferum* (Ehrb.) Deflandre was found restricted to samples 18-3 and 18-4 in the Cannonball member, Fort Union formation.

Frequency.—"Infrequent."

Genus **MICRHYSTRIDIUM** Deflandre, 1937

Michrhystridium Deflandre, 1937, Ann. Paleont., vol. 26, p. 79.

Michrhystridium Deflandre, Pasiels, 1948, Mus. d'Hist. Nat. de Belgique, Mem., No. 109, p. 45.

Michrhystridium Deflandre, Valensi, 1953, Soc. Géol. Français, Mem., n.s., vol. 32, No. 68, p. 39.

Michrhystridium Deflandre, Stockmans and Williere, 1960, Senck. leth., vol. 41, No. 1/6, p. 4.

Micrhystridium Deflandre emended Staplin, 1961, Paleont., vol. 4, pt. 3, p. 408.

Micrhystridium Deflandre, Eisenack, 1962, Neues Jb. Geol. Paleont. Monatsh, no. 2, p. 95.

Micrhystridium Deflandre emended Downie and Sarjeant, 1963, Palaeont., vol. 6, No. 1, p. 92.

Type species.—*Micrhystridium inconspicuum* (Deflandre), Deflandre, 1937.

Description.—Cysts spherical to subspherical, ornamented with threadlike appendages that are slightly broader at their proximal end and taper distally. Size generally less than 20 μ .

Discussion.—The original interpretation of the genus is used herein inasmuch as all the species fall within Deflandre's description. It should be pointed out that they also fall into Staplin's emendation of genus.

***Micrhystridium piliferum* Deflandre, 1937**

Pl. 23, figs. 3-5

Micrhystridium piliferum Deflandre, 1937, Ann. Paleont., vol. 26, p. 32, pl. XV, fig. 11.

Holotype.—AF74, Deflandre, 1937.

Description.—Cysts spherical to subspherical, diameter about 21-22 μ , membrane thickness on the order of 1 μ or less. Processes hair to bristle-like, length about 8-9 μ ; thickness on the order of 1 μ at base and narrows distally. Space between adjacent processes approximately 3 μ .

Occurrence.—The specimens assignable to this species are all from sample 18-4 of the Cannonball member, Fort Union formation.

Frequency.—"Infrequent."

Family **PTEROSPERMOPSIDAE** Eisenack, 1954

Genus **PTEROSPERMOPSIS** W. Wetzel, 1952

Pterospermopsis W. Wetzel, 1952, Geol. Jb., vol. 66, p. 411.

Pterospermopsis W. Wetzel, Eisenack, 1954, Palaeontographica, pt. A, vol. 105, p. 70.

Pterospermopsis W. Wetzel, Deflandre and Cookson, 1955, Australian Jour. Marine and Freshwater Res., vol. 6, No. 2, p. 286.

Pterospermopsis W. Wetzel, Gerlach, 1961, Neues Jb. Geol. Paleont., vol. 112, No. 2, p. 209.

Type species.—*Pterospermopsis danica* W. Wetzel, 1952.

Description.—A problematical microfossil consisting of a more or less globular body surrounded by a membrane-like flange. The body is devoid of any tetrad mark.

Distribution.—The number of species thus far assigned to this genus is limited. The type species comes from sediments of Danian age. Eisenack and Gerlach found another species in sediments of Miocene age, whereas the species assigned to this genus by Deflandre and Cookson are of Lower Cretaceous age, Upper Cretaceous age and lower Tertiary age.

***Pterospermopsis australiensis* Deflandre and Cookson Pl. 23, figs. 8-9**

Pterospermopsis australiensis Deflandre and Cookson, 1955, Australian Jour. Marine Freshwater Res., vol. 6, No. 2, p. 286.

Holotype.—Not listed by Deflandre and Cookson.

Description.—Central body more or less spherical; body wall smooth but folded due to compression; diameter of body about 12 μ . Membrane-like flange thin but appears to be regularly folded; flange width 8-10 μ .

Discussion.—The specimens herein assigned to *Pterospermopsis australiensis* fall well within the size range as given by Deflandre and Cookson for the species.

Occurrence.—This species, as far as is known, has been restricted to sediments of Lower Cretaceous age. The occurrence of specimens of *Pterospermopsis australiensis* in Paleocene sediments presents a problem as it might represent specimens of Lower Cretaceous age reworked into the Paleocene or, it might extend the range of the species. There is evidence of little reworked older material in the Cannonball member, the present feeling is that the range of the species, at least in the South Dakota area, does extend into the Paleocene.

Frequency.—"Infrequent."

DIVISION CHLOROPHYTA

Family HYDRODICTYACEAE

Genus **PEDIASTRUM** Meyen 1829

Pediastrum Meyen, Brunnthaler, 1915, Die Süsswasser-flora Deutschlands, Österreichs und Schweiz, vol. 5, pt. 2, p. 89.

Pediastrum Meyen, Fritsch, 1935, The Structure and Reproduction of the Algae, vol. 1, p. 167.

Pediastrum Meyen, Wilson and Hoffmeister, 1953, Amer. Jour. Sci., vol. 25, p. 753.

Pediastrum Meyen, Gray, 1960, Jour. Paleont., vol. 34, No. 3, p. 456.

Description.—Disk-shaped coenobia with coenocytes arranged

into a single layer. Size of coenobium and shape of peripheral cells variable.

Discussion.—The characteristic arrangement of cells forming the coenobia makes identification of specimens assignable to this genus simple.

Distribution.—Records of fossil *Pediastrum* are not too common in the literature. Wilson and Hoffmeister described four new species of *Pediastrum* from sediments of probably Eocene age of Sumatra. Cookson in 1953 described and illustrated one species of *Pediastrum* from the late Tertiary clays of Australia. Dr. Jane Gray described several species of *Pediastrum* from sediments of the middle Mascall formation of Oregon. The writer has observed coenobia of *Pediastrum* in samples of the Green River shale of Eocene age of Utah. Recently, Evitt (1963,c) described some specimens of *Pediastrum* from the Lower Cretaceous of Pakistan making this the oldest known occurrence of representatives of this algal genus.

***Pediastrum* cf. *P. boryanum* (Turpin) Meneghini**

Pl. 23, fig. 10

Pediastrum boryanum (Turp.), Menegh., Brunnthaler, 1915, Die Süßwasserflora Deutschlands, Österreichs und Schweiz, vol. 5, pt. 2, p. 100, fig. 61.

Pediastrum boryanum (Turp.), Menegh., Fritsch, 1935, The Structure and Reproduction of the Algae, vol. 1, p. 167.

Pediastrum boryanum (Turp.), Menegh., Cookson, 1953, Mem. Nat. Mus. Melbourne, vol. 18, p. 110, pl. 1, figs. 7-11.

Pediastrum boryanum (Turp.), Menegh., Gray, 1960, Jour. Paleont., vol. 34, No. 3, p. 457.

Description.—Disk-shaped coenobia with the peripheral coenocytes bearing two conical, blunt-tipped processes. Size and number of cells in coenobia variable.

Discussion.—The specimens encountered are compared with *Pediastrum boryanum* because they are close to this species as described by Brunnthaler, (1915) and Fritsch (1935). Definite assignment is not made at this time because the specimens observed are badly corroded.

The appearance of freshwater algae together with marine organisms at first may appear contradictory. A similar association was recently reported by Evitt (1963c). There is little doubt that the coenobia of *Pediastrum*, as well as many of the spores and pollen of terrestrial plants, were carried into the marine realm by seaward

flowing streams during Paleocene time. The corroded nature of the specimens of *Pediastrum* tends to support this interpretation.

Occurrence.—*Pediastrum* cf. *boryanum* was found to occur only in sample 18-3 of the Cannonball member, Fort Union formation.

Frequency.—"Infrequent."

DIVISION BRYOPHYTA

Class MUSCI

Family SPHAGNACEAE

Genus SPHAGNUM (Dill.) L., 1753

- Sphagnumsporites* Raatz, 1937, Abb. preuss. geol. L.-A.N.F., vol. 183, p. 9.
Triletes Cookson, 1947 (in part), B.A.N.Z. Antarctic Res. Expedition 1929-31, Rep. Ser. A., vol. 2, p. 136.
Nigrina Malivkina, 1949 (in part), Determination of Spores and Pollen, p. 69.
Sphagnites Cookson, 1953, Australian Jour. Bot., vol. 1, No. 3, p. 463.
Sterisporites Pflug in Thomson and Pflug, 1953, Palaeontographica, vol. 94, pt. B, p. 53.
Sphagnumsporites Raatz, Potonie, 1956, Beih. Geol. Jb., vol. 23, p. 17.
Sphagnum (spores) Tchigouriaeva, 1956, Atlas of Tertiary Microspores of the U.S.S.R., Univ. Kharkow, p. 36.
Sphagnites Cookson, Balme, 1957, Phys. and Chem. Survey of the National Coal Res., Commonwealth of Australia, Ref. No. T.C. 25, p. 15.
Sphagnum (spores) Drozhastchich and Purtova in Samoilovitch, *et al.*, 1961. Pollen and Spores from Western Siberia, p. 13.

Description.—Trilete isospores; outline in polar view circular to subcircular; size usually small. Exine psilate to variously ornamented, wall thickness moderate. Tetrad mark distinct, ray length about $\frac{1}{2}$ spore radius.

Distribution.—*Sphagnum* (bog or peat moss) is represented by several hundred species and, at present, is world wide in its distribution. It is known to grow only in moist areas. The abundance of fossil representatives of this genus in the South Dakota lignites and the associated allochthonous sediments suggests that this area was poorly drained in early Tertiary time.

***Sphagnum antiquasporites* Wilson and Webster, 1946** Pl. 27, figs. 1-5

- Sphagnum antiquasporites* Wilson and Webster, 1946, Amer. Jour. Bot., vol. 33, p. 273, fig. 2.
Sphagnumsporites antiquasporites (Wilson and Webster), Potonie, 1956, Beih. Geol. Jb., vol. 23, p. 17.

Holotype.—Slide 352C-2, Wilson and Webster, 1946.

Description.—Trilete isospores; outline in polar view subcircu-

lar; diameter 20-28 μ . Exine psilate; wall thickness 1 to 1.5 μ ; Trilete rays distinct, length approximately $\frac{1}{2}$ spore radius.

Differential diagnosis.—*Sphagnum antiquasporites* Wilson and Webster is differentiated from *S. australe* (Cookson) by its distinctly smaller diameter and its thinner-walled exine.

The specimens described herein are slightly larger in size than those described by Wilson and Webster, 1946. In all other respects, they fit the original specific description.

Occurrence.—*Sphagnum antiquasporites* was found to be present in most samples from Zones I and II in the Cave Hills section and in Zones I, II and III from the Crow Butte section.

Frequency.—"Infrequent" to "Abundant."

Sphagnum australe (Cookson), Drozh., 1961

Pl. 27, figs. 10-11

Triletes australis Cookson, 1947, B.A.N.Z. Antarctic Res. Expedition, Rep. Ser. A., vol. 2, p. 136, pl. 15, figs. 58, 59.

Sphagnites australis (Cookson), Cookson, 1953, Australian Jour. Bot., vol. 1, No. 3, p. 463.

Stereisporites megastercoides Pflug in Thomson and Pflug, 1953, Palaeontographica, vol. 94, pt. B, p. 53, pl. 1, fig. 74.

Sphagnusporites australis (Cookson), Potonie, 1956, Beih. Geol. Jb., vol. 23, p. 17.

Sphagnites australis (Cookson), Balme, 1937, Phys. Chem. Survey of the National Coal Resources, Commonwealth of Australia, Ref. No. T.C. 25, p. 15, pl. 1, figs. 1-3.

Sphagnum suflavum Bolkhovitina, 1959, Trudy Geol. Inst., U.S.S.R., No. 24, p. 82, pl. 1, fig. 3b.

Sphagnum australis (Cookson), Drozhastchich in Samoilovitch, *et al*, 1961, Pollen and Spores from Western Siberia, p. 14, pl. 1, figs. 2a, 2b, 3a and 3b.

Holotype.—No holotype was designated by Cookson in her 1947 paper or 1953 paper.

Description.—Trilete isospores; outline in polar view subcircular to subtriangular; equatorial diameter 29-36 μ . Exine psilate, wall thickness about 2 μ . Trilete ray distinct, length approximately $\frac{1}{2}$ spore radius.

Differential diagnosis.—*Sphagnum australe* (Cookson) is separated from *S. antiquasporites* Wilson and Webster by its distinctly larger size and its thicker walled exine.

Occurrence.—This species was found to occur in Zone I of both the Crow Butte and the North Cave Hills sections. Originally, this species was described by Cookson (1947) from lower Tertiary lignites of the Kerguelen Archipelago. Balme (1957) reported this

species from the lower Mesozoic sediments of Western Australia.

Frequency.—"Infrequent."

***Sphagnum australe parvum* (Cookson), n. comb.**

Pl. 27, figs. 6-9

Sphagnites australis parva Cookson, 1953, Australian Jour. Bot., vol. 1, No. 3, p. 464, pl. 1, fig. 1.

Sphagnumsporites australis parva (Cookson), Potonie, 1956, Beih. Geol., Jb., vol. 23, p. 17.

Holotype.—None designated by Cookson.

Description.—Trilete isospores; outline in polar view subcircular to subtriangular; equatorial diameter 20-30 μ . Exine psilate; wall thickness about 2 μ . Trilete mark distinct, ray length about $\frac{1}{2}$ spore radius.

Differential diagnosis.—*Sphagnum australe parvum* (Cookson) is distinguished from *S. australe* (Cookson) by its distinctly smaller size and from *S. antiquasporites* Wilson and Webster by its thicker exine wall.

Occurrence.—This subspecies was found to occur in samples from the upper part of Zone I of both the North Cave Hills section and the Crow Butte section. In the southern Australian area, Cookson found this species to occur in both the Upper Cretaceous Coomaum coal and the lower Tertiary Wensleydale clay.

Frequency.—In the Harding County, South Dakota area, this species occurs "infrequently" to "commonly."

***Sphagnum regium* Drozh.**

Pl. 27, figs. 12-17

Sphagnum regium Drozhastichich in Samoilovitch, *et al.*, 1961, Pollen and Spores from Western Siberia, p. 18, pl. 2, figs. 1a-d, 2, 3.

Holotype.—Preparation N. 7931a, V.N.I.G.R.I.; pl. 2, figs. 1a-d.

Description.—Trilete isospore; outline in polar view circular to subcircular; equatorial diameter 20-25 μ . Exine sculptured with grana on proximal and distal surface; amb smooth; wall thickness about 1 μ . Granate sculpture better developed on distal surface; diameter of sculpture elements approximately 2 μ . Trilete mark distinct; ray length $\frac{1}{2}$ spore radius.

Differential diagnosis.—The moderately large grana and the relatively small diameter of the spore readily separate this species from similar species assigned to *Sphagnum* in this paper.

Occurrence.—*Sphagnum regium* Drozh. appears to be restricted to Maestrichtian and Paleocene sediments of the Western Siberian

lowlands. In Harding County, South Dakota, this species was found to occur in the upper part of Zone I of the North Cave Hills section.

Frequency.—"Common."

DIVISION TRACHEOPHYTA

Class LYCOPODINEAE

Family LYCOPODIACEAE (Provisional assignment)

Genus FOVEASPORIS Krutzsch, 1959

Foveasporis Krutzsch, 1959, *Geologie*, vol. 8, Nos. 21-22, p. 162.

Type species.—*Foveasporis fovearis* Krutzsch, 1959.

Description.—Trilete isopores; outline in polar view distinctly triangular to distinctly circular. Exine moderate in thickness; sculpture foveate (not foveolate; see Krutzsch, 1959, p. 39). Trilete mark distinct; length of ray $\frac{2}{3}$ to almost full radius.

Differential diagnosis.—The presence of a foveate sculpture distinguishes this genus from other similar genera.

Distribution.—Krutzsch (1959) assigned certain Mesozoic (Dogger and Lias), species as well as some Tertiary species, to his new genus.

***Foveasporis triangulus* Stanley, n. sp.**

Pl. 27, figs. 18-22

Holotype.—Slide 1-11B; location 45.2×107.9 ; Pl. 27, figs. 18-19.

Isotype.—Slide D-7-5 (NS); location 39.9×106.2 ; Pl. 27, fig. 22.

Type locality.—North Cave Hills, Harding Co., South Dakota.

Type horizon.—Ludlow member, Fort Union formation, Paleocene.

Name derivation.—*Triangulus*=having three angles; after the characteristically triangular shape of specimens of this species.

Description.—Trilete isopores; outline in polar view triangular with sides weakly concave to weakly convex; equatorial diameter 32-40 μ . Endexine approximately 0.5 μ thick; ectexine sculpture foveate with muri 2 μ high at junctions and 1 μ high between muri junctions giving the spore a knobby appearance; lumen width 2-3 μ . Trilete mark distinct; length of rays about $\frac{3}{4}$ to almost full radius. A more or less indistinct frill parallels the ray.

Differential diagnosis.—*Foveasporis triangularis*, n. sp. is distinguished from *F. reticulatus* (Cookson), Krutzsch, 1959 by its distinctly triangular shape and its smaller lumina. Similarly, *F.*

triangularis, n. sp. is distinguished from *F. agathoeccus* Krutzsch, *F. linearis* Krutzsch and *F. fovearis* Krutzsch by its triangular shape and from *F. torifovearis* Krutzsch and *F. microfovearis* Krutzsch by its smaller size.

Botanical affinities.—Similar to spores of the *Selaginella repanda* group.

Occurrence.—*Foveosporis triangularis*, n. sp. was found only in two samples from the central part of Zones I and II of the North Cave Hills section.

Frequency.—"Infrequent."

Genus **FOVEOSPORITES** Balme, 1957

Foveosporites Balme, 1957, Phys. Chem. Survey of the National Coal Res., Commonwealth of Australia, Ref. No. T.C. 25, p. 17.

Foveosporites Balme, Potonie, 1960, Beih. Geol. Jb. vol. 34, p. 46.

Type species.—*Foveosporites canalis* Balme, 1957.

Description.—Trilete isospores; outline in polar view subcircular to subtriangular. Exine moderate in thickness; sculpture foveolate with lumina usually separated from one another by a distance of at least the width of a lumen. Trilete mark distinct, lips slightly to moderately raised; rays more or less reach the equator.

Differential diagnosis.—As pointed out by Potonie (1960, p. 46), *Foveosporites* is distinguished from *Foveotriletes* by the presence of more widely separated lumina. The foveolate sculpture differentiates this genus from *Foveasporis* Krutzsch.

Distribution.—*Foveosporites* Balme was first reported from questionable Lower Cretaceous sediments of Western Australia. The occurrence of a representative of the genus in the Upper Cretaceous sediments of South Dakota extends the range of the genus.

Foveosporites canalis Balme, 1957

Pl. 28, figs. 1-5

Foveosporites canalis Balme, 1957, Phys. Chem. Survey of the National Coal Res., Commonwealth of Australia, Ref. No. T.C. 25, p. 17, pl. 1, figs. 15-17.

Holotype.—T.S. 330, Balme, 1957.

Description.—Trilete spores; outline in polar view subtriangular to subcircular; equatorial diameter 30-40 μ . Endexine approximately 0.5 μ thick; ectexine 1.5 μ thick, foveolate with elongated

lumina up to $3\ \mu$ long in the proximal region; in the distal area, the lumina are more or less circular and about $1\ \mu$ wide. Trilete mark distinct, length of ray approximately $\frac{3}{4}$ spore radius; a thickened lip is present.

Differential diagnosis.—This species is separated from *F. cyclicus*, n. sp. by its generally smaller size, thicker exine, and elongated pits in the proximal region.

Botanical affinities.—Similar to spores produced by the *Lycopodium verticillatum* group.

Occurrence.—*Foveosporites canalis* was only observed in samples from Zones II and III of the Crow Butte section.

Frequency.—"Infrequent."

Foveosporites cyclicus Stanley, n. sp.

Pl. 28, figs. 6-10

Holotype.—Slide G 1-8a-2; location 30.9×108.7 ; Pl. 28, figs 8-10.

Isotype.—Slide G 1-8a-2; location 30.0×101.9 ; Pl. 28, figs. 6-7.

Type locality.—North Cave Hills, Harding Co., South Dakota.

Type horizon.—Ludlow member, Fort Union formation, Paleocene.

Name derivation.—*Cyclus*=circle, ring; after the circular lumina in the proximal region.

Description.—Trilete isospores; outline in polar view subcircular to subtriangular; equatorial diameter $37\text{--}45\ \mu$. Exine $1.5\ \mu$ thick with no obvious layering, foveolate; lumina about $1\ \mu$ wide, circular in proximal region and becoming elongated near spore periphery. Trilete ray distinct, length about $\frac{3}{8}$ radius.

Differential diagnosis.—This species differs from *F. canalis* Balme in that the size is larger (although there is some overlap) and the exine is slightly thinner. Also, *F. cyclicus*, n. sp. has round lumina in the proximal region whereas in *F. canalis* Balme they are elongated.

Botanical affinities.—Similar spores are produced by members of the *Lycopodium verticillatum* group.

Occurrence.—This species was found to occur only in the upper part of Zone I of the North Cave Hills section.

Frequency.—"Infrequent."

Genus **HAMULATISPORIS** Krutzsch, 1959

Hamulatisporis Krutzsch, 1959, Geol., vol. 8, Nos. 21-22, p. 157.

Type species.—*Hamulatisporis hamulatis* Krutzsch, 1959.

Description.—Trilete iso or microspores; outline in polar view subtriangular to circular. Exine hamulately sculptured with sculpture best developed on distal hemisphere of grain and slightly to markedly reduced on proximal hemisphere; exine thickness moderate. Trilete mark distinct; ray length $\frac{3}{4}$ spore radius.

Differential diagnosis.—The hamulate sculpture serves to distinguish this genus from similar genera.

Distribution.—Krutzsch tentatively assigned forms described by Rudolph (1935) from the upper Tertiary and other forms described by Rogalska (1954) from the Lias to this genus. In South Dakota, species occur in both the Upper Cretaceous and lower Tertiary sediments.

Hamulatisporis amplus Stanley, n. sp.

Pl. 29, figs. 1-6

Holotype.—Slide SCBO-6; location 35.7×105.6 ; Pl. 29, figs. 1-3.

Isotype.—Slide S8-1a-6; location 36.4×117.1 ; Pl. 29, figs. 4-5.

Type locality.—Crow Butte, Harding Co., South Dakota.

Type horizon.—Hell Creek formation, Maestrichtian.

Name derivation.—*Amplus*=large; after the large size of specimens of this species.

Description.—Trilete iso or microspores; outline in polar view circular to subcircular; equatorial diameter $50-70 \mu$. Exine sculpture elements consist of tortuous muri that are most pronounced on the distal surface; height of muri on distal face 3μ . Trilete mark distinct to more or less indistinct; ray approximately reaches equator.

Differential diagnosis.—*Hamulatisporis amplus*, n. sp. is distinguished from *H. hamulatis* Krutzsch by its distinctly larger size.

Botanical affinities.—Possibly *Lycopodium*.

Occurrence.—*Hamulatisporis amplus*, n. sp. was found to occur in Zones I and III of the Crow Butte section and in Zone I of the North Cave Hills section.

Frequency.—"Common."

Hamulatisporis hamulatis Krutzsch, 1959

Pl. 29, figs. 7-8

Hamulatisporis hamulatis Krutzsch, 1959, *Geologie*, vol. 8, Nos. 21-22, p. 157, pl. 29, figs. 326-328.

Holotype.—Reference number not given; illustrations pl. 29, figs. 326-328, Krutzsch, 1959.

Description.—Trilete iso or microspores; outline in polar view circular to subcircular; equatorial diameter 27-34 μ . Endexine approximately 0.5 μ thick; ectexine elements consist of tortuous muri with a height of 2 μ on distal surface and absent to weakly developed on proximal surface.

Differential diagnosis.—*Hamulatisporis hamulatis* Krutzsch is distinguished from *H. amplus*, n. sp. by its smaller size.

Botanical affinities.—Possibly *Lycopodium*.

Occurrence.—*Hamulatisporis hamulatis* Krutzsch was only observed in samples from Zone I of the Crow Butte section. Krutzsch originally described this species from the Eocene of Germany.

Frequency.—"Infrequent" to "common."

Family **SELAGINELLACEAE** (Provisional assignment)

Genus **CINGULATISPORITES** Pflug, emended Potonie, 1956.

Cingulatisporites Pflug, 1953, in Thomson and Pflug, 1953, *Palaeontographica*, vol. 94, pt. B, p. 58.

Cingulatisporites Pflug, Delcourt and Sprumont, 1955, *Soc. Belge de Géol., Mém., N.S.4, No. 5*, p. 38.

Cingulatisporites Pflug, emended Potonie, 1956, *Beih. Geol. Jb.*, vol. 23, p. 58.

Cingulatisporites Pflug, Krutzsch, 1959, *Geologie*, vol. 8, Nos. 21-22, p. 175.

Cingulatisporites Pflug, Pocock, 1961, *Jour. Paleont.*, vol. 35, No. 6, p. 1234.

Type species.—*Cingulatisporites levispeciosus* Pflug, 1953.

Description.—Trilete microspores; outline in polar view more or less circular; size moderate. Exine psilate to perhaps scabrate. Trilete rays full to almost full radius of spore body; rays do not go on to the cingulum. Width of cingulum less than 1/5 spore body diameter.

Differential diagnosis.—*Cingulatisporites* is distinguished from other cingulate genera by its more or less psilate to scabrate exine and by its narrow cingulum of constant width.

Cingulatisporites dakotaensis Stanley, n. sp.

Pl. 30, Figs. 1-8

Holotype.—Slide G 1-10-1; location 35.5 $\times$ 110.7; Pl. 30, figs. 6-8.

Isotype.—Slide G 1-12a-2; location 39.4 $\times$ 112.6; Pl. 30; fig. 1.

Type locality.—North Cave Hills, Harding Co., South Dakota.

Type horizon.—Ludlow member, Fort Union formation, Paleocene.

Name derivation.—*Dakotaensis*=from Dakota; after the state in which the type locality is situated.

Description.—Trilete microspores; outline in polar view sub-circular to subtriangular; distinct cingulum present; equatorial diameter, excluding cingulum 24-28 μ ; width of cingulum 4-5 μ . Exine psilate, thickness 1 μ . Tetrad mark distinct to indistinct; length of ray moderate to long; rays occasionally extended up to but not on to the cingulum; a Y-shaped thickened area that is rotated 60° in relation to the tetrad mark is always distinctly present on the distal area. Cingulum psilate, transparent.

Differential diagnosis.—*Cingulatisporites dakotaensis*, n. sp. is differentiated from *C. radiatus*, n. sp. by its homogeneous and transparent cingulum that lacks radiating striations.

Botanical affinities.—Possibly *Selaginella*.

Occurrence.—This species was found to be distributed more or less throughout Zone I and the upper part of Zone II of the North Cave Hills section. It also occurred occasionally in one sample from the Crow Butte section.

Frequency.—"Infrequent" to "common."

Cingulatisporites radiatus Stanley, n. sp.

Pl. 30, figs. 9-16

Holotype.—Slide G 1-8a-2; location 29.7 $\times$ 96.7; Pl. 30, figs. 13-14.

Isotype.—Slide G 1-8a-1; location 39.2 $\times$ 107.2; Pl. 30, fig. 12.

Type locality.—North Cave Hills, Harding Co., South Dakota.

Type horizon.—Ludlow member, Fort Union formation, Paleocene.

Name derivation.—*Radiatus*=rayed; after the raylike striations on the cingulum.

Description.—Trilete microspore; outline in polar view sub-circular to subtriangular; distinct cingulum present; equatorial diameter, excluding cingulum, 23-30 μ ; width of cingulum 4-5 μ . Exine psilate, thickness 1 μ . Tetrad mark distinct to indistinct, length of ray moderate to long, occasionally extending up to, but never on to the cingulum; a Y-shaped thickening that is rotated 60° in relation to the tetrad mark is always distinctly present on the distal area of the spore. Cingulum psilate, usually yellow-brown in color and possessing radially directed striations.

Differential diagnosis.—*Cingulatisporites radiatus*, n. sp. differs

from *C. dakotaensis*, n. sp. by the presence of radially directed striations on the cingulum.

Botanical affinities.—Probably *Selaginella*.

Distribution.—This species was found to occur in samples from the upper part of Zone I of the North Cave Hills section.

Frequency.—"Infrequent."

Class **FILICINEAE**

Family **DICKSONIACEAE** (Provisional assignment)

Genus **ALSOPHILIDITES** Cookson ex Potonie, 1956

Alsophilidites Cookson, 1947, B.A.N.Z. Antarctic Res. Expedition, 1929-31, Rep. Ser. A., vol. 2, p. 136.

Alsophilidites Cookson ex Potonie, 1956, Beih. Geol. Jb., vol. 23, p. 14.

Type species.—*Alsophilidites kerguelensis* Cookson, 1947.

Description.—Trilete isospores, outline in polar view triangular with sides slightly to moderate in thickness; sculpture wanting. Trilete mark distinct, length of ray equals spore radius.

Differential diagnosis.—The long trilete rays separate this organ genus from other similar organ genera.

Distribution.—To the writer's knowledge, this genus has thus far been reported only from lower Tertiary sediments.

Alsophilidites kerguelensis Cookson

Pl. 28, figs. 11-14

Alsophilidites kerguelensis Cookson, 1947, B.A.N.Z. Antarctic Res. Expedition, Rep. Ser. A., vol. 2, p. 136, pl. 16, fig. 69.

Holotype.—Slide number not given by Cookson; illustration in Cookson, 1947, pl. 16, fig. 69.

Description.—Trilete isospores; shape triangular in polar view with apexes more or less well rounded and with sides straight to slightly concave or slightly convex. Spore diameter 25-32 μ . Trilete rays reach equator. Exine psilate.

Occurrence.—*Alsophilidites kerguelensis* Cookson occurs throughout Zone I and most of Zone II of the North Cave Hills section. It has also been observed in the upper part of Zone I of the Crow Butte section.

Frequency.—"Infrequent."

Family **GLEICHENIACEAE**

Genus **GLEICHENIA** Smith, 1793

Deltoidospora Miner, 1935, Amer. Midland Nat., vol. 16, No. 4, p. 618.

- Gleichenia* (spores) Selling, 1946, Bishop Museum Special Pub. No. 37, p. 31.
Gleichenioidites Ross, 1949, Bull. Geol. Inst. Uppsala, vol. 34, p. 31.
Gleichenia (spores) Pokrovskaja, 1950, Analyse Pollinique, p. 112.
Gleichenioidites Ross emended Delcourt and Sprumont, 1955, Mém. Soc. Belge Géologie, N.S. 4, No. 5, p. 26.
Gleichenia (spores) Harris, 1955, New Zealand Dept. of Sci. Ind. Res., Bull. 116, p. 70.
Gleichenioidites Ross, Potonie, 1956, Beih. Geol. Jb., vol. 23, p. 14.
Gleichenia (spores) Couper, 1958, Palaeontographica, vol. 103, pt. B, p. 113.
Gleichenioidites Ross, Krutzsch, 1959, Geologie, vol. 8, Nos. 21-22, p. 109.
Gleichenia (spores) Grigorjeva in Samoilovitch, *et al.*, 1961, Pollen and Spores from Western Siberia, p. 44.

Description.—Trilete isopores; outline in polar view triangular with sides slightly to moderately concave. Exine psilate, thickness moderate except in equatorial region between apices where exine is thicker. Trilete rays distinct, rays reach to or almost to the spore equator.

Differential diagnosis.—Spores herein assigned to *Gleichenia* Smith are separated from other spores assigned to organ genera by the characteristically thick exine in the equatorial region between apices.

Discussion.—Because one can not recognize all the spores produced by all the species of *Gleichenia* is no reason for not assigning some dispersed spores to this genus. It is realized that the members of *Gleichenia* produce a great variety of spores (including monolete spores). Nevertheless, it is thought that some spores can be assigned with a fair degree of confidence to the genus.

Distribution.—At present the genus *Gleichenia* is restricted to the tropical, subtropical, and south temperate regions of the world. Four species are indigenous to Hawaii and, as mentioned by Selling (1946, p. 32), *Gleichenia* is the most abundant fern represented in the forests of Hawaii.

***Gleichenia circinidites* Cookson, 1953**

Pl. 28, figs. 15-16

Gleichenia circinidites Cookson, 1953, Australian Jour. Bot., vol. 1, No. 3, p. 464, pl. 1, figs. 5, 6.

Holotype.—None listed by Cookson.

Description.—Trilete isospore; outline in polar view triangular with sides concave and apices more or less pointed; equatorial diameter 25-40 μ . Exine psilate; thickness at apices 1 μ ; up to 2 μ thick between apices. Trilete mark distinct, ray length almost equals radius of spore.

Differential diagnosis.—*Gleichenia circinidites* Cookson somewhat resembles *G. senonicus* (Ross) but is differentiated from it by the more pointed apices. In *G. triangulara*, n. sp., the apices are more rounded than in *G. senonicus* (Ross).

Occurrence.—*Gleichenia circinidites* Cookson was found in several samples from Zone I and in some samples from Zone II of the Cave Hills section. It also was found to occur in one sample from the Crow Butte section.

Frequency.—"Infrequent" to occasionally "common."

***Gleichenia triangulara* Stanley, n. sp.**

Pl. 28, figs. 17-19

Holotype.—Slide S 8-2-10; location 27.9 $\times$ 110.3; Pl. 28, figs. 17-18.

Isotype.—Slide S 8-2-8; location 31 $\times$ 106.4; Pl. 28, fig. 19.

Type locality.—Crow Butte, Harding Co., South Dakota.

Type horizon.—Hell Creek formation, Maestrichtian.

Name derivation.—*Triangulus*-triangle; after the triangular outline of specimens of this species.

Description.—Trilete isospores; outline in polar view triangular with rounded apices and straight to slightly concave sides; equatorial diameter 18-25 μ . Exine psilate, thickness about 1.5 μ between apices and about 0.5 μ at apices. Trilete mark distinct; length of ray approximately equals that of spore radius; a kyrtole parallels the rays.

Differential diagnosis.—*Gleichenia triangulara*, n. sp. is differentiated from *G. circinidites* Cookson by its smaller size and more rounded apices. This species differs from *G. senonicus* (Ross), n. comb. by having straighter sides and the presence of a kyrtole.

Occurrence.—*Gleichenia triangulara*, n. sp. was found to occur only in a sample from Zone I of the Crow Butte section.

Frequency.—"Infrequent."

Family **GLEICHENIACEAE** (Provisional assignment)

Genus **CARDIOANGULINA** Mal. emended Potonie, 1960

Cardioangulina Malawkina, 1949, Geol. Invest. All-Union Petroleum Institute, U.S.S.R., p. 36.

Cardioangulina Malawkina emended Potonie, 1960, Beih. Geol. Jb., vol. 39, p. 28.

Type species.—*Cardioangulina trichacantha* Malawkina.

Description.—Trilete isopores, outline in polar view triangular with apices well rounded and sides slightly to markedly concave. Exine psilate, thickness of exine moderate. Trilete mark distinct with length of rays about $\frac{1}{2}$ spore radius.

Differential diagnosis.—This genus is readily distinguished from both *Alsophilidites* and *Cyathidites* by its distinctly shorter trilete rays. In *Deltoidospora*, the apices are not so well rounded and the sides are either only slightly concave or convex. In addition, the rays are somewhat longer in *Deltoidospora*.

Cardioangulina diaphana (Wilson and Webster), new comb.

Pl. 30, figs. 17-21

Deltoidospora diaphana Wilson and Webster, 1946, Amer. Jour. Bot., vol. 33, p. 273, fig. 3.

Holotype.—Slide 345 C-1, Wilson and Webster, 1946.

Description.—Trilete isopores; outline in polar view triangular with well rounded apices; sides usually slightly concave; equatorial diameter 25-40 μ . Exine psilate, thickness about 1 μ . Trilete mark distinct, length of ray close to $\frac{1}{2}$ spore radius.

Discussion.—Specimens herein assigned to *Cardioangulina diaphana* (Wilson and Webster) have for a long time been assigned to the genus *Deltoidospora* Miner. The writer did this in a previous work (1960) mainly because of his unawareness of Malawkina's paper and because the organ genus *Deltoidospora* at that time seemed best to fit the species.

Differential diagnosis.—Although the writer has not seen Malawkina's 1949 paper, *Cardioangulina diaphana* (Wilson and Webster) is readily distinguished from *C. trichacantha* Malawkina by its much smaller size. Potonie (1960, p. 29) gave 80 μ for the diameter of the latter species.

Occurrence.—*Cardioangulina diaphana* (Wilson and Webster) was found to be present in many samples from Zone I and Zone II of the North Cave Hills section. It was also found to be present in many samples from the Twin Butte section and in one sample from the Crow Butte section.

Frequency.—"Infrequent" to occasionally "common."

Family **HYMENOPHYLLACEAE** (Provisional assignment)

Genus **HYMENOPHYLLUMSPORITES** Rouse, 1957

Hymenophyllumsporites Rouse, 1957, Canadian Jour. Bot., vol. 35, p. 363.

Hymenophyllumsporites Rouse, Potonie, 1960, Beih. Geol. Jb., vol. 39, p. 30.

Type species.—*Hymenophyllumsporites deltoida* Rouse, 1957.

Description.—Trilete isopores; outline in polar view subtriangular to subcircular. Exine psilate; thickness moderate. Trilete mark distinct; length of ray about $\frac{2}{3}$ to $\frac{3}{4}$ spore radius; lists bordering rays weakly to moderately well-developed.

Differential diagnosis.—*Hymenophyllumsporites* Rouse is distinguished from all other psilate trilete organ genera by its large size and relatively long trilete rays. *Lygodiumsporites* Potonie, Thomson, and Thiergart, for example, has a similar size range but the trilete rays are distinctly shorter.

Hymenophyllumsporites furcosus Stanley, n. sp.

Pl. 31, figs. 1-5

Holotype.—Slide G 1-11-1; location 21.1 $\times$ 112.7; Pl. 31, figs. 1-2.

Isotype.—Slide S 1-8a-6; location 38.6 $\times$ 101.4; Pl. 31, fig. 3.

Type locality.—North Cave Hills, Harding Co., South Dakota.

Type horizon.—Ludlow member, Fort Union formation, Paleocene.

Name derivation.—*Furca*=fork; after the forked distal ends of the trilete rays.

Description.—Trilete isospore; outline in polar view subtriangular to subcircular; equatorial diameter 40-60 μ . Endexine 0.5 μ thick; ektexine 1 μ thick, psilate. Trilete mark distinct, ray length about $\frac{3}{4}$ of spore radius; a thickened lip borders ray; the distal ends of the ray are often forked.

Differential diagnosis.—This species is distinguished from *H. deltoida* by its smaller size and its thinner exine. *Hymenophyllumsporites furcosus*, n.sp. is separated from *Leiotriletes pseudomaximus* (Pflug and Thomson) by the thickened ray borders and by the forked distal extremities of the rays themselves.

Occurrence.—This new species was observed in a sample from the upper part of Zone I of the Crow Butte section and from samples from Zone I of the North Cave Hills section.

Frequency.—"Infrequent."

Family **OSMUNDACEAE**Genus **OSMUNDA** L., 1753

Osmunda (spores) Pokrovskaja, 1950, *Analyse Pollinique*, p. 116.

Rugulatisporites Pflug in Thomson and Pflug, 1953, *Palaeontographica*, vol. 94, pt. B, p. 56.

Osmundacidites Couper, 1953, *New Zealand Geol. Sur. Paleont., Bull.* 22, p. 20.

Osmundacidites Couper, Potonie, 1956, *Geol. Jb.*, vol. 23, p. 30.

Osmunda (Spores) Klimko in Samoilovitch, *et al.*, 1961, *Pollen and Spores from Western Siberia*, p. 112.

Description.—The spores assigned to the genus *Osmunda* in this paper have the following characteristics:

Trilete isopores; outline in polar view triangular to circular, often badly crumpled; size variable. Exine thickness thin to moderate; ornamentation elements grana, bacula, clavae, coni, spinae, or a combination of any of these elements that are always absent or reduced on the proximal surface. Trilete mark indistinct to distinct; ray length long.

Distribution.—The genus *Osmunda*, at present, is limited from temperate to tropical areas and is often associated with wet or swampy environments.

***Osmunda comaumensis* (Cookson), n. comb.**

Pl. 31, figs. 6-9

Triletes comaumensis Cookson, 1953, *Australian Jour. Bot.*, vol. 1, No. 3, p. 470, pl. 2, figs. 27, 28.

Osmundacidites comaumensis (Cookson), Balme, 1957, *Phys. Chem. Survey of the National Coal Resources, Commonwealth of Australia, Ref. T.C.* 25, p. 25, pl. 4, figs. 54-56.

Osmundacidites comaumensis (Cookson), Balme, Cookson and Dettmann, 1958, *Proc. Roy. Soc. Victoria*, vol. 70, pt. 2, p. 100, pl. 14, fig. 13.

Holotype.—Illustrated on pl. 2, fig. 28, Cookson, 1953; also refigured on pl. 14, fig. 13, Cookson and Dettmann, 1958.

Description.—Trilete isopores, shape more or less spherical but may appear highly irregular due to crumpling; diameter 45-65 μ . Endexine approximately 0.5 μ thick; ectexine elements bacula, spinae and clavae with a length of up to 2 μ . Trilete mark distinct to indistinct, length of rays long but not reaching the equator.

Differential diagnosis.—*Osmunda comaumensis* (Cookson), n. comb. is differentiated from *Osmunda wellmanii* (Couper) by the longer sculpture elements of the former species.

Occurrence.—*Osmunda comaumensis* (Cookson) was found to occur in many samples from Zones I and II in the Cave Hills section and in Zone I of the Crow Butte section.

Frequency.—“Infrequent” to “common.”

Family **POLYPODIACEAE** (Provisional assignment)

Genus **LAEVIGATOSPORITES** (Ibrahim) emended S. W. & B., 1944

Laevigatosporites Ibrahim in Potonie, Ibrahim and Loose, 1933, Neues Jb. Min., vol. 67, pt. B, p. 39.

Polypodiumsporites Raatz, 1937, Abb. preuss. geol. L.-A.N.F., No. 183, p. 10.

Phaseolites Wilson and Coe, 1940, Amer. Midland Nat., vol. 23, No. 1, p. 182.

Laevigatosporites Ibrahim emended Schopf, Wilson, and Bentall, 1944, Illinois Geol. Sur. Rep. Invest., No. 91, p. 36.

Monolites Erdtman, 1947, Svensk Bot. Tidskrift, vol. 41, pt. 1, p. 110.

Laevigatosporites Ibrahim emend. S. W. and B., Kosanke, 1950, Illinois Geol. Sur. Bull. 74, p. 27.

Laevigatosporites Ibrahim, Potonie and Kremp, 1954, Geol. Jb., vol. 69, p. 165.

Monolites Erdtman emend. Potonie, 1956, Beih. Geol. Jb., vol. 23, p. 77.

Polypodiaceasporites Potonie, 1956, Beih. Geol. Jb., vol. 23, p. 76.

Laevigatosporites Ibrahim, Potonie, 1956, Beih. Geol. Jb., vol. 23, p. 75.

Laevigatosporites Ibrahim, Potonie and Kremp, 1956, Palaeontographica, vol. 99, pt. B, II, p. 137.

Laevigatosporites Ibrahim, Manum, 1963, Norsk Polarinstitut, No. 125, p. 20.

Type species.—*Laevigatosporites vulgaris* (Ibrahim), Ibrahim, 1933.

Description.—Monolete isospores; outline in lateral equatorial view reniform to ovaloid; size moderate; exine psilate thickness moderate; monolete mark distinct and straight.

Discussion.—As mentioned by Stanley (1960, p. 103) and also more recently by Manum (1962, p. 20), Potonie (1956) would like to preserve the organ generic name *Laevigatosporites* for Paleozoic psilate monolete spores and place younger psilate monolete species in the organ genus *Polypodiaceasporites*. He claimed (Potonie, 1956, p. 76) that *Laevigatosporites* Ibrahim “. . . is differentiated from younger spores of more or less similar outline by spores whose exine is usually less rigid.” If this were true it still would be almost impossible to differentiate between Paleozoic and younger *Laevigato*-type spores unless one knew before hand which sample was from Paleozoic and which from younger strata. Theoretically there should be a difference between Paleozoic and younger *Laevigato*-type spores, but until it is more clearly defined one is forced to place them together in the same organ genus. A slightly less rigid exine is a poor and entirely subjective criterion for organ generic separation.

Differential diagnosis.—The psilate exine of *Laevigatosporites* separates it from other monolite organ genera.

Botanical affinities.—*Laevigatosporites* is generally attributed to the fern family Polypodiaceae which, among other types of spores, produces monolete bean-shaped spores. The Polypodiaceae presently have a world-wide distribution "over most of the land areas of the earth, especially abundant in forests and humid areas, but occurring in almost all floristic areas or zones from desert to rain forests and from tropics to arctic or antarctic" (Lawrence, 1955, p. 349). The occurrence of *Laevigatosporites* in the Cretaceous and Paleocene sediments in South Dakota seems to reflect the diverse habitat of the Polypodiaceae for it has been found in almost all samples collected from environments represented by lignites, clays, mudstones and sands. Schopf, Wilson, and Bentall (1944, p. 36) related the *Laevigatosporites* forms to at least three Paleozoic plant groups, the Filicineae, Sphenopsida, and the Pteridospermae.

***Laevigatosporites haardti* (Pot. and Ven.) Thom. and Pf., 1953**

Pl. 32, figs. 1-3

Sporites haardti Potonie and Venitz, 1934, Arb. Inst. Palaeobot., vol. 5, p. 13, pl. 1, fig. 13.

Laevigatosporites gracilis Wilson and Webster, 1946, Amer. Jour. Bot., vol. 33, p. 273, fig. 4.

Monolites minor Cookson, 1947, B.A.N.Z. Antarctic Res. Expedition, 1929-31, Rept. Ser. A., vol. 2, pt. 8, p. 135, pl. 15, fig. 57.

Laevigatosporites haardti (Pot. and Ven.), Thomson and Pflug, 1953, Palaeontographica, vol. 94, pt. B, p. 59, pl. 3, figs. 27-38.

Laevigatosporites haardti (Pot. and Ven.), Thomson and Pflug, 1953, Manum, 1962, Norsk Polarinstitut, No. 125, p. 21, pl. 1, fig. 1.

Holotype.—Sample 34, VII 27, 15.5: 64:0.

Description.—Monolete isospores; outline in lateral equatorial view typically reinform; length of major diameter 25-70 μ . Exine psilate, thickness 1-2 μ ; in proximal area the exine is slightly thicker; color yellow-brown to translucent. Monolete mark distinct, length approximately $\frac{2}{3}$ maximal diameter.

Differential diagnosis.—This species is usually distinguished from *Laevigatosporites ovatus* Wilson and Webster by its characteristic bean-shape and by the presence of a somewhat thicker exine in the proximal region.

Occurrence.—*Laevigatosporites haardti* (Pot. and Ven.), Thom. and Pf. was found to occur in practically all samples from the Crow Butte, the North Cave Hills and the Twin Butte sections.

Frequency.—"Infrequent" to "abundant."

Laevigatosporites ovatus Wilson and Webster, 1946 Pl. 32, figs. 4-6

Laevigatosporites ovatus Wilson and Webster, 1946, Amer. Jour. Bot., vol. 33, p. 273, fig. 5.

Monolites major Cookson, 1947, B.A.N.Z. Antarctic Res. Expedition, 1929-31, Rep. Ser. A., vol. 2, p. 135.

Laevigatosporites discordatus Pflug in Thomson and Pflug, 1953, Palaeontographica, vol. 94, pt. B, p. 59. pl. 3, figs. 39-44.

Holotype.—Slide 345C-2, Wilson and Webster.

Description.—Monolete isospores; outline in lateral equatorial view ovaloid with polar area slightly flattened; length of major diameter 30-90 μ . Exine psilate; thickness 1-2 μ ; color yellow-brown to translucent. Monolete mark distinct, length approximately $\frac{1}{2}$ maximal diameter.

Differential diagnosis.—*Laevigatosporites ovatus* Wilson and Webster is distinguished from *L. haardti* (Pot. and Ven.), Thom. and Pf. by its subcircular rather than its bean-shaped outline in lateral view and by the absence of any thickening of the exine in the proximal polar area. However, it must be mentioned that, because of preservation conditions or orientation of the grain on the slide, it is sometimes difficult, if not impossible to differentiate between specimens of *L. haardti* and *L. ovatus*.

Occurrence.—This species along with *Laevigatosporites haardti* was found to occur in almost all samples from the Crow Butte, North Cave Hills and Twin Butte sections.

Frequency.—"Infrequent" to "abundant."

Genus **LEIOTRILETES** Naumova, ex Potonie and Kremp, 1954

Leiotriletes Naumova, 1937, Report XVII Int. Geol. Congress, p. 355.

Leiotriletes Naumova ex Potonie and Kremp, 1954, Geol. Jb., vol. 69, p. 120.

Leiotriletes Naumova ex Potonie and Kremp, 1954, Palaeontographica, vol. 98, pt. B, p. 36.

Leiotriletes (Naumova), Potonie and Kremp, Krutzsch, 1959, Geologie, vol. 8, No. 21-22, p. 56.

Leiotriletes (Naumova), Potonie and Kremp, Krutzsch, 1962, Atlas, pt. 1, p. 7.

Type species.—*Leiotriletes sphaerotriangulus* (Loose), Potonie and Kremp, 1954, Krutzsch, 1962, Atlas, pt. 1, p. 7.

Description.—Trilete isospores with a subtriangular to subcircular outline in polar view. Exine thin to moderate, sculpture wanting to weakly developed. Trilete rays distinct, ray length about $\frac{3}{4}$ spore radius.

Differential diagnosis.—*Leiotriletes* (Naumova) is separated from *Hymenophyllumsporites* Rouse by having simple rays that lack lists.

Botanical Affinities.—Some members of this organ genus are similar to spores produced by *Lygodium* of the Schizaeaceae as well as some members of the Polypodiaceae.

Leiotriletes pseudomaximus (Pflug and Thomson), n. comb.

Pl. 31, figs. 10-12

Laevigatisporites pseudomaximus Pflug and Thomson in Thomson and Pflug, 1953, *Palaeontographica*, vol. 94, pt. B, p. 54, pl. 2, figs. 18-23.

Leiotriletes maxoides maximus Krutzsch, 1962, *Atlas*, pt. 1, p. 20.

Holotype.—None designated.

Description.—Trilete isospores; outline in polar view subcircular to subtriangular; equatorial diameter 45-70 μ . Exine psilate to scabrate; thickness approximately 1 to 2 μ . Trilete mark distinct, ray length about $\frac{1}{2}$ spore radius.

Discussion.—*Leiotriletes pseudomaximus* (Pflug and Thomson) was originally assigned to *Laevigatisporites* which is an organ genus for megaspores. Therefore, it had to be reassigned. Krutzsch, 1959 (p. 56) subdivided many of the lower and middle Tertiary forms of *Leiotriletes* into many subspecies. This detailed subdivision is presently not thought to be warranted as there appears to be continuous gradation between his many subspecies rather than any natural break.

Differential diagnosis.—This species is distinguished from *Hymenophyllum furcosus*, n. sp. by the absence of thickened ray borders.

Occurrence.—*Leiotriletes pseudomaximus* (Pflug and Thomson), n. comb. was observed to occur in many samples from the Twin Butte section, from Zones I and II of the North Cave Hills section and also in samples from Zones I and II of the Crow Butte section.

Frequency.—"Infrequent" to "common."

Genus **LEPTOLEPIDITES** Couper, 1953

Leptolepidites Couper, 1953, *New Zealand Geol. Sur. Paleont. Bull.* 22, p. 28.

Leptolepidites Couper, Potonie, 1956, *Beih. Geol. Jb.*, vol. 23, p. 27.

Type species.—*Leptolepidites verrucatus* Couper, 1953.

Description.—Trilete isospores; outline in polar view subtriangular to subcircular. Exine verrucate; wall thickness moderate to thick. Trilete mark distinct to somewhat indistinct; ray length $\frac{3}{4}$ to full spore radius.

Discussion.—Couper, 1953, described *Leptolepidites* as having a thick exine. Specimens encountered from South Dakota and assigned to this genus have an exine wall of moderate thickness and, therefore, the generic description of *Leptolepidites* is slightly emended to include these forms.

Differential diagnosis.—According to Potonie (1956, p. 27), *Leptolepidites* has verrucae "which are of more or less similar size and approximately circular" which differentiates it from *Converrucosisporites*, *Verrucosisporites* and *Trilites*.

Botanical affinities.—*Leptolepidites* somewhat resembles spores of the genus *Leptolepia* of the Polypodiaceae, a family of more or less world-wide distribution.

***Leptolepidites tenuis* Stanley, n. sp.**

Pl. 32, figs. 7-11

Holotype.—Slide SCB 11-11; location 45.6×101.2 ; Pl. 32, figs. 7-8.

Isotype.—Slide SCB 11-6; location 26.1×102.2 ; Pl. 32, figs. 9-10.

Type locality.—Crow Butte, Harding Co., South Dakota.

Type horizon.—Hell Creek formation, Maestrichtian.

Name derivation.—*Tenuis*=thin; after the thin endexine characteristic of this species.

Description.—Trilete isospores; outline in polar view subcircular; equatorial diameter 30-40 μ . Endexine 1 μ thick; ectexine elements verrucae with a diameter of about 5 μ and a height of approximately 3 μ . Trilete mark distinct to indistinct; length of rays about $\frac{3}{4}$ spore radius.

Differential diagnosis.—*Leptolepidites tenuis*, n. sp. is distinguished from *L. verrucatus* Couper by its much thinner exine.

Occurrence.—*Leptolepidites tenuis*, n. sp. was observed to occur only in samples from the lower part of Zone II of the Crow Butte section.

Frequency.—"Infrequent."

Family **SALVINACEAE**Genus **AZOLLA** Lamarek, 1783Subsection **EUAZOLLA**

The following list of references on *Azolla* have been seen by the writer. For a more complete list, the reader is referred to the bibliography in the paper by Duigan and Cookson, 1957, p. 12.

Azolla Lam. (spores), Arnold, 1955, Cont. Mus. Paleont., Univ. of Mich., vol. 12, No. 4, p. 37.

Azolla Lam. (spores), Duigan and Cookson, 1957, Proc. Roy. Soc. Victoria, vol. 69, p. 5.

Azolla Lam. (spores), Tschudy, 1961, Wyoming Geol. Assoc. Guidebook, p. 55.

Azolla Lam. (spores), Krutzsch, 1962, Atlas, pt. 1, p. 70, 71.

Description.—Massula—round to oval in outline, size range 100 μ to perhaps well over 500 μ ; characterized by appendages that bear anchor-shaped processes on a moderately long shaft (glochidia). Megaspores—trilete, size range on order of 200-400 μ ; a gullalike structure is present on the proximal pole and the entire spore is covered with a perispore. Microspores—trilete, size about 30 μ ; the exine, in at least some members appears to be slightly granular.

Differential diagnosis.—The massula and the megaspore of *Azolla*, subsection *Euazolla* are quite distinctive. The microspores unfortunately, are not distinctive and, as no isolated microspores were observed, it is entirely possible that they may have been confused with spores of some other fern group.

Distribution.—*Azolla* is presently restricted to tropical and subtropical regions of the world. It is also indicative of a wet habitat.

***Azolla cretacea* Stanley, n. sp.**

Pl. 33, figs. 1-5

Holotype.—Slide 8-1a-2; location 2 8.0 $\times$ 106.4; Pl. 33, figs. 4-5.

Type locality.—Crow Butte, Harding Co., South Dakota.

Type horizon.—Hell Creek formation, Maestrichtian.

Name derivation.—*Cretacea* after Cretaceous, the age of the horizon from which the holotype was selected.

Description.—Massulae more or less small for *Azolla* microspore massula; size 110-208 μ . Glochidia approximately 30 μ long, width of stalk slender and of uniform diameter throughout with the exception of proximal end where the stalk becomes decidedly nar-

rower. Distal end of glochidia bear an anchor-shaped structure. Microspores within massula are trilete and have a diameter of about 30 μ .

Discussion.—To the writer's knowledge, this Cretaceous occurrence of *Azolla* is the oldest record of the genus. Arnold (1955, p. 40) wisely predicted the occurrence of *Azolla* in the "late Mesozoic."

Neither microspores occurring outside of the massula nor megaspores were observed in any of the samples. The latter, because of their large size, might not have been transferred to the slide during preparation. The absence of the microspores is puzzling and may be explained by nonrecognition. However, it should be mentioned that the slides were carefully examined for the *Azolla* microspores.

Differential diagnosis.—*Azolla cretacea*, n. sp. is differentiated from *Azolla filiculoides* var. *rubra* Strasburger as described by Duigan and Cookson (1957) by not having septated glochidia. *Azolla primaeva* (Penhallow) Arnold, 1955 has glochidia that are of uniform width throughout their entire width and, therefore, differ from the glochidia of *Azolla cretacea*, n. sp. The specimens of *Azolla* massula illustrated by Tschudy (1961, p. 54) appears to be identical or similar to *A. cretacea*, n. sp. However, Tschudy gave no description of the specimens he illustrated.

Occurrence.—Crow Butte (Maestrichtian) and North Cave Hills (Paleocene), Harding County, South Dakota.

Frequency.—Zone I, Crow Butte (Maestrichtian)—"infrequent." Zone II, North Cave Hills (Paleocene)—"common."

Family **SCHIZAEACEAE**

Genus **ANEMIA** Swartz, 1806

Cicatricosisporites Potonie and Gelletich, 1933, S.B. Ges. nat. Freunde, vol. 33, p. 522.

Mohrioidites Thiergart, 1950, Geol. Jb., vol. 65, p. 84.

Anemia Swartz (spores), Pokrovskaja, 1950, Analyse Pollinique, p. 114.

Mohriospores Potonie, 1951, Palaeontographica, vol. 91, pt. B, p. 137.

Appendicisporites Weyland and Krieger, 1953, Palaeontographica, vol. 95, pt. B, p. 12.

Liratosporites Vishnu-Mittre, 1954, The Palaeobotanist, vol. 3, p. 119.

Mohriospores Cookson, 1954, Proc. Roy. Soc. Victoria, vol. 66, p. 112.

Appendicisporites Weyland and Krieger, Delcourt and Sprumont, 1955, Mémoires de la Société Belge de Géologie, N.S. 4, No. 5, p. 39.

- Appendicisporites* Weyland and Krieger, Potonie, 1956, Beih. Geol. Jb., vol. 23, p. 56.
Cicatricosisporites Potonie and Gelletich, Potonie, 1956, Beih. Geol. Jb., vol. 23, p. 47.
Anemia Swartz (spores), Erdtman, 1957, An Intro. to Palynology, pt. 2, p. 78.
Radiatisporites Cookson and Dettmann, 1958, Roy. Soc. Victoria, vol. 70, pt. 2, p. 103.
Appendicisporites Weyland and Krieger, Krutzsch, 1959, Z. Geologie, vol. 8, No. 21-22, p. 115.
Cyclosporites Cookson and Dettmann, 1959, Australian Jour. Sci., vol. 21, No. 8, p. 260.
Anemia Swartz (spores), Popov and Kupchinskaia, 1960, Geol. and Geophys. No. 11, p. 95.
Anemia Swartz (spores), Markova in Samoilovitch, *et al.*, 1961, Pollen and Spores from Western Siberia, p. 64.
Cicatricosisporites Potonie and Gelletich, Kedves, 1961, Pollen et Spores, vol. 3, No. 1, p. 124.
Anemia Swartz (spores), Potonie, 1962, Beih. Geol. Jb., vol. 52, p. 103.

Description.—Trilete isospores; size variable; outline in polar view triangular to perhaps subcircular. Sculpture elements consist of cicatricose or caniculate muri that may parallel the spore sides, radiate from a central position or perhaps be arranged in some other pattern. Thimble-like thickenings to elongated horn or spinelike appendages may be present at the apexes of some forms.

Discussion.—The reader is referred to the excellent monograph on the Schizaeaceae by Bolkhovitina (1961) and especially to Plates 26-31 in this work.

Differential diagnosis.—The muronate sculpturing appears to be characteristic of the genus *Anemia*. It should be noted that at least one species illustrated by Bolkhovitina (1961), *A. trichorhiza* Gardn. (extant) lacks this sculpturing.

Distribution.—The members of *Anemia* are at present restricted to tropical and subtropical regions. According to Lawrence, two species are indigenous to the southern part of the United States.

***Anemia radiata* (Krutzsch), new comb.**

Pl. 33, figs. 6-7

Cicatricosisporites paradoragensis group, Krutzsch, 1957, Z. Angewandte Geol., vol. 3, p. 514, pl. 1, figs. 38-44.

Cicatricosisporites radiatus Krutzsch, 1959, Palaeontographica, vol. 105, pt. B, p. 126.

Holotype.—Illustrated on plate 1, figure 41, 42, Krutzsch, 1957.

Description.—Trilete isospore; outline in polar view subcircular to subtriangular; equatorial diameter 40-50 μ . Exine pattern caniculate with muri on the proximal surface radiating from a narrow

ridge that parallels the rays; muri height up to $5\ \mu$; vallae average about $1\ \mu$ in width. Trilete mark distinct; ray length equals spore radius.

Discussion.—It is with fair confidence that this species is assigned to the extant genus *Anemia*. If the reader does not feel so confident, then it should be reassigned to the genus *Cyclosporites* Cookson and Dettmann, 1959 rather than to *Cicatricosisporites* inasmuch as spores with radiating muri have been separated from *Cicatricosisporites* Potonie and Gelletich.

Differential diagnosis.—*Anemia radiata* (Krutzsch) differs from *Cyclosporites hughesi* Cookson and Dettmann in having a caniculate rather than a cicatricose sculpture.

Occurrence.—*Anemia radiata* (Krutzsch), new comb. was found to occur in samples from only the upper part of Zone I of the North Cave Hills section. According to Krutzsch (1957, 1959) the *Anemia* type spores with radiating sculpture are restricted from the upper Eocene to Pliocene. The occurrence of this *A. radiata* (Krutzsch) in the Paleocene sediments of South Dakota slightly extends the range of the group downward.

Frequency.—"Infrequent."

Anemia tricornitata (Weyland and Greifeld), new comb. Pl. 33, figs. 8-9

Appendicisporites tricornitatus Weyland and Greifeld, 1953, *Palaeontographica*, vol. 95, pt. B, pl. 43, pl. 1, fig. 52.

Appendicisporites tricornitatus Weyland and Greifeld, Delcourt and Sprumont, 1955, *Mém. Soc. Belge Géologie*, N.S. 4, No. 5, p. 40, pl. 4, fig. 3.

Appendicisporites tricornitatus Weyland and Greifeld, Kremp, Ames and Grebe, 1957, *Catalog of Fossil Spores and Pollen*, vol. 2, p. 52.

Appendicisporites tricornitatus Weyland and Greifeld, Couper, 1958, *Palaeontographica*, vol. 103, pt. B, p. 135, pl. 17, figs. 7-9.

Appendicisporites tricornitatus Weyland and Greifeld, Bolkhovitina, 1961, *Trudy Geol. Inst., S.S. S.R.*, vol. 40, p. 60, pl. 16, figs. 9a-c.

Holotype.—Not preserved; original material at Geological Institute, University of Köln.

Description.—Trilete isospores; outline in polar view triangular with slightly convex sides; equatorial diameter $42\text{--}53\ \mu$. Endexine $1\ \mu$ thick; ectexine muronate with five muri present on proximal side of spore; muri have parallel sides and are $3\ \mu$ high and about $2\ \mu$ wide; vallae about $1\ \mu$ wide. Trilete ray distinct, length of ray almost equals spore radius. Thimble-like appendages located at each apex of spore; appendage $6\ \mu$ long and about $6\ \mu$ wide at base.

Discussion.—The specimens here described are larger in size than the type illustrated by Weyland and Greifeld, 1953. In addition, the South Dakota specimens have slightly convex sides whereas the holotype has almost straight sides. In all other respects the specimens encountered agree with the species description of Weyland and Greifeld.

Differential diagnosis.—The caniculate sculpture and the thimble-like appendages distinguish *A. tricornitata* from other similar species. Verbitskaia (1958, pl. II) illustrated some specimens which appear to be similar to *A. tricornitata* (Weyland and Greifeld). No description of these forms, which she called a new species, appears in the work and, therefore, it is difficult to make any specific comparison.

Occurrence.—*Anemia tricornitata* (Weyland and Greifeld), new comb. was found to occur in samples from Zone II the Crow Butte section.

Frequency.—"Infrequent."

Genus **SCHIZAEA** Smith, 1798

- Schizaea* Smith (spores), Selling, 1946, Spec. Pub. 37, Bishop Mus., p. 29.
Schizaea Smith (spores), Selling, 1946, Medd. fran Goteborgs bot. Tradgard, vol. 16, p. 5.
Schizaea Smith (spores), Selling, 1947, Svensk Bot. Tidskrift, vol. 41. No. 4, p. 439.
Schizaea Smith (spores), Pokrovskaja, 1950, Analyse Pollinique, p. 113.
Schizacoisporites Potonie, 1951, Palaeontographica, vol. 91, pt. B, p. 144.
Cicatricosporites Pflug and Thomson in Thomson and Pflug, 1953, Palaeontographica, vol. 94, pt. B, p. 61.
Schizacoisporites Potonie, Delcourt and Sprumont, 1955, Mém. Soc. Belge Géologie, N.S. 4, No. 5, p. 46.
Schizacoisporites Potonie, Potonie, 1956, Beih. Geol. Jb., vol. 23, p. 81.
Schizaea Smith (spores), Cookson, 1957, Roy. Soc. Victoria, Proc., vol. 69, p. 42.
Reticulosporis Krutzsch, Krutzsch, 1959, Arch. Nat. Meckl., vol. 5, p. 39.
Cicatricosporites Pflug and Thomson, Krutzsch, 1959, Geologie, vol. 8, Nos. 21-22, p. 220.
Schizacoisporites Potonie emended Krutzsch, 1959, Geologie, vol. 8, Nos. 21-22, p. 226.
Reticulosporis Krutzsch, 1959, Geologie, vol. 8, Nos. 21-22, p. 228.
Schizacoiipollenites Potonie emended Potonie, 1960, Beih. Geol. Jb., vol. 39, p. 70.
Schizacoisporites Potonie, Bolkhovitina, 1961, Trudy Geol. Inst., S.S.S.R., vol. 40, p. 33.
Schizaea Smith (spores), Bolkhovitina, 1961, Trudy Geol. Inst., S.S.S.R., vol. 40, p. 16.

Description.—Monolete (rarely trilete) isospores with a reni-

form to subelliptical outline in lateral equatorial view. Sculpture reticulate, striate, granulate, or psilate. Exine thickness moderate.

Discussion.—The reticulate and striate forms of this genus are distinctive and thought to be easily recognizable. It is realized that the granulate and psilate forms present a problem as they may be easily confused with spores produced by other fern families. Because the spores of some members of the genus are not readily recognizable is no reason to not assign spores of recognizable members to the genus.

For a detailed survey of *Schizaea* the reader is referred to the classical work by Selling (1946) and also to the more recent major monograph by Bolkhovitina (1961).

Differential diagnosis.—The reticulate members of the genus are characterized by a mesh with small lumina. The striate species are also distinctive and are not thought to be confusable with any other type of spore. It should be mentioned that pollen of the gymnosperm genus *Ephedra* produces pollen similar in sculpturing to the striate members of *Schizaea*. The monolete mark can be used to separate these two genera. The granulate and psilate spores of *Schizaea* present a problem and no data can be presented at this time on recognizing and distinguishing these spores from similar spores produced by other genera.

It is interesting to note that Selling (1946) believed that there was a decrease in spore size, perhaps due to the reduction of the gametophytic generation, in the more advanced extant members of the *Schizaea*. There is no obvious reduction in size through time as shown by the fossil members described to date.

Distribution.—*Schizaea*, at present, is primarily a tropical and subtropical genus of the Southern Hemisphere. As Selling (1974, p. 4) pointed out one species is found as far north as Newfoundland.

***Schizaea plectilis* Stanley, n. sp.**

Pl. 34, fig. 1-3

Holotype.—Slide S 8-1a-2; location 39.8 × 107.4; Pl. 34, figs. 1-3.

Type locality.—Crow Butte, Harding Co., South Dakota.

Type horizon.—Hell Creek formation, Maestrichtian.

Name derivation.—*Plectilis*=complicated, intricate; after the complicated construction of the muri.

Description.—Monolete isospores; outline in lateral equatorial and polar views subcircular; length of major axis 80-95 μ . Exine 1.5 μ thick, reticulately sculptured with complex muri; lumina circular to subcircular, width about 3 μ ; the construction of the muri consists of a narrow central ridge with many shorter ridges set at right angles to the central ridge giving a yardarm appearance or form (as for example, the septa in the Devonian coral *Helio-phyllum*). Monolete mark distinct, length of ray approximately $\frac{3}{4}$ that of major axis.

Differential diagnosis.—The absence of a tectum and the presence of distinctive muri readily separate this species from *S. triangulara*, n. sp. The muri also separate *S. plectilis*, n. sp. from all other presently described schizaeaceaous spores.

Occurrence.—*Schizaea plectilis*, n. sp. was found to occur only in one sample from Zone I of the Crow Butte section.

Frequency.—"Infrequent."

Schizaea triangulara Stanley, n. sp.

Pl. 34, figs. 4-9

Holotype.—Slide 1-8ab; location 29.0 $\times$ 102.3; Pl. 34, figs. 4-7.

Isotype.—Slide G 1-8a-5; location 28.2 $\times$ 98.6; Pl. 34, figs. 8-9.

Type locality.—North Cave Hills, Harding Co., South Dakota.

Type horizon.—Ludlow member, Fort Union formation, Paleocene.

Name derivation.—*Triangulus*=triangle; after the triangular cross-section of the tectum supporting elements.

Description.—Monolete isospores; outline in lateral equatorial view more or less subcircular with the polar area slightly flattened; length of major axis 45-75 μ . Exine tectate with tectum supported by hexagonally arranged elements that form triangular lumina. Tectum about 1 μ thick; supporting elements about 0.5 μ long and endexine 1.5 μ thick. Monolete ray $\frac{1}{2}$ to about $\frac{3}{4}$ length of major axis; lip of ray slightly thickened.

Differential diagnosis.—*Schizaea triangulara*, n. sp. appears to closely resemble *S. promensis* Cookson (as illustrated in Cookson, 1957, pl. 8, fig. 3; Kremp and Ames, 1962; Bolkhovitina, 1961, pl. 7, fig. 1). Cookson made no mention of a tectum in her des-

cription and this appears to be the major difference between the two species.

Occurrence.—*Schizaea triangulara*, n. sp. was found to occur only in one sample from Zone I of the North Cave Hills section.

Frequency.—"Infrequent."

Family **SCHIZAEACEAE** (Provisional assignment)

Genus **TRIPLANOSPORITES** Pflug, 1952

Triplanosporites Pflug, 1952, *Palaeont. Z.*, vol. 26, p. 113.

Triplanosporites Pflug emended Pflug in Thomson and Pflug, 1953, *Palaeontographica*, vol. 94, pt. B, p. 58.

Triplanosporites Pflug, Potonic, 1956, *Beih. Geol. Jb.*, vol. 23, p. 16.

Triplanosporites Pflug, Krutzsch, 1959, *Geologie*, vol. 8, Nos. 21-22, p. 83.

Triplanosporites Pflug, Krutzsch, 1962, *Atlas*, pt. 1, p. 8.

Type species.—*Triplanosporites sinuosus* (Pflug), Pflug, 1952.

Description.—Trilete iso or microspores; outline in equatorial view ovaloid; polar axis always longer than equatorial axis. Exine psilate to perhaps scabrate. Trilete mark distinct, rays reach to, or almost to, spore periphery.

Discussion.—There has been some discussion (Deak, 1959) as to whether or not *Triplanosporites* Pflug is a naturally occurring group or whether it is a preservation phenomenon. For purposes of an artificial genus it does not make any difference as in either alternative the name would be valid in the case of *Triplanosporites*. The interesting paper by Deak (*op. cit.*) shows that both triangular and triplane specimens can be found among spores of *Lygodium polymorphum* (Cav.) H.B.K. It should be pointed out that, among the triplane variations illustrated by Deak, no specimen has a polar axis longer than the equatorial axis. This evidence as well as examination of many specimens suggests to this writer that the specimens assigned to *Triplanosporites* are indeed distinctive, from a natural group and are not preservation phenomena of other trilete spores.

Differential diagnosis.—The long polar axis and the shorter equatorial axis separate *Triplanosporites* Pflug from other similar trilete spore genera.

Distribution.—As shown by the works of Thomson and Pflug (1953) and Krutzsch (1959, 1962), *Triplanosporites* occurs regularly in the lower Tertiary sediments of Central Europe. Its absence

is noticeable in the papers by Samoilovitch, *et al.*, 1961 and Manum, 1962. The Samoilovitch paper described pollen and spores from western Siberia (mainly north of 55 north latitude) whereas Manum described lower Tertiary (probably Paleocene-Eocene) sediments from Spitsbergen (mainly north of 77 north latitude). This evidence tends to suggest that the genus *Triplanosporites* was confined to the central European region and did not extend into the more northern areas.

Botanical affinities.—Schizaeaceae?

***Triplanosporites sinuosus* Pflug, 1952**

Pl. 35, figs. 1-5

Triplanosporites sinuosus Pflug, 1952, *Palaeont. Z.*, vol. 26, Nos. 1-2, p. 114, fig. 2.

Triplanosporites sinuosus Pflug, Pflug in Thomson and Pflug, 1953, *Palaeontographica*, vol. 94, pt. B, pl. 58, pl. 3, figs. 5-16.

Triplanosporites sinuosus Pflug, Delcourt and Sprumont, 1955, *Mém. Soc. Belge Géologie*, N.S. 4, No. 5, p. 45, pl. 2, fig. 7.

Triplanosporites sinuosus Pflug, Krutzsch, 1959, *Geologie*, vol. 8, Nos. 21-22, p. 85, pl. 7, figs 46-51, pl. 8, figs. 52-58.

Triplanosporites sinuosus Pflug, Krutzsch, 1962, *Atlas*, pt. 1, p. 42, pl. 14, figs. 17-18.

Holotype.—Not preserved.

Description.—Trilete iso or microspores; outline equatorial view ovaloid with proximal end usually flattened and the distal end usually pointed; polar axis longer than maximal equatorial diameter; length of polar axis 35-60 μ ; greatest equatorial width usually always proximal of spore center. Exine psilate to perhaps weakly scabrate; endexine about 0.3 μ thick; ectexine 1.2 μ thick except in proximal region where thickness is always greater than elsewhere and may reach slightly over 4 μ in thickness. Trilete rays distinct with length of ray approximately equaling the spore radius.

Differential diagnosis.—The size range readily separates this species from those described by Krutzsch, 1962.

Occurrence.—*Triplanosporites sinuosus* Pflug was observed to be present in most samples from Zones I and II of the North Cave Hills section and also was occasionally present on slides from the uppermost sample from the Crow Butte section.

Frequency.—"Infrequent" to "common."

Genus **TOROISPORIS** Krutzsch, 1959

Toroisporis Krutzsch, 1959, *Geologie*, vol. 8, Nos. 21-22, p. 90.

Toroisporis Krutzsch, Krutzsch, 1962, *Atlas*, pt. 1, p. 11.

Type species.—*Toriosporis torus* (Pflug), Krutzsch, 1959.

Description.—Trilete iso or microspores; outline in polar view subcircular to subtriangular; size moderate. Exine psilate; trilete mark distinct and moderate in length. Tori or krytomes always present.

Discussion.—This genus was created in 1959 by Krutzsch to fill an apparent gap that existed for trilete spores with convex sides and krytomes. In 1953, Pflug designated the genus *Concavisporites* for spores with krytomes and concave sides. Spores with krytomes and convex sides were assigned by Pflug to *Laevigatisporites*. In 1956 Potonie noted that the type species of *Laevigatisporites* is a "megaspore" (in this case a spore with a diameter of 200 μ or more). Therefore, smaller spores probably should not be assigned to this artificial "megaspore" genus.

Differential diagnosis.—The convex sides and the presence of krytomes separate this organ genus from other similar organ genera.

Botanical affinities.—Schizaeaceae?

Toroisporis major (Pflug), new comb.

Pl. 35, figs. 6-9

Sporites neddeni Potonie, 1931, *Braunkohle*, vol. 30, pl. 1, fig. 5.

Sporites neddeni Potonie, Potonie, 1934, *Arb. Inst. Palaeob.*, vol. 4, p. 36, pl. 1, fig. 12.

Concavisporites obtusangulus (Potonie) *major* Pflug, n. comb., n. subsp. in Thomson and Pflug, 1953, *Palaeontographica*, vol. 94, pt. B, p. 50, pl. 1, fig. 42.

Toroisporis (*Toroisporis*) *torus* (Pflug) *major* (Pflug), Krutzsch, 1959, *Geologie*, vol. 8, Nos. 21-22, p. 95, pl. 9, figs. 68-69.

Sporites neddeni Potonie, Kremp and Ames, 1961, *Catalog of Fossil Spores and Pollen*, vol. 14, p. 73.

Holotype.—Not preserved.

Description.—Trilete iso or microspores; outline in polar view circular to subtriangular; equatorial diameter 33-55 μ . Exine psilate to occasionally scabrate; thickness 1.5-2 μ . Trilete mark distinct; length of rays about $\frac{2}{3}$ spore radius. A distinct krytome always present; the trilete rays usually extend up to or slightly beyond the krytome.

Discussion.—In 1959, when Krutzsch formed the genus *Toroi-*

sporis he also recombined many species and subspecies previously assigned to other genera into his new organ genus. Many of these subspecies, on the one hand, are distinct morphologically. On the other hand, many are not and the nomenclature involved with some of these subspecies is unduly cumbersome and unwieldy. Therefore, the subspecies described as *Concavisporites obtusangulus* (Potonie) *major* Pflug is transformed to the genus *Toroisporis* Krutzsch and raised to the level of species.

Differential diagnosis.—As mentioned above Krutzsch recombined many species and subspecies into his genus *Toroisporis*. Many of these recombinations were apparently done solely on the basis of the existing literature (a good part of which includes poor illustrations and still poorer descriptions). Therefore, it is felt that perhaps much of this will have little value and serves only to complicate the existing literature. The reader is referred to Table 5, opposite page 108 in Krutzsch, 1959 for Dr. Krutzsch's interpretation for the difference between this species and other similar species and subspecies.

Occurrence.—*Toroisporis major* (Pflug) n. comb. was found to be present in many samples from Zones I and II of the North Cave Hills section.

Frequency.—"Infrequent" to "common."

INCERTAE FAMILIAE SPORES

Genus **RETICULATASPORITES** Leschik, 1955

Reticulatasporites Leschik, 1955, Schweiz. Palaeont., vol. 72, p. 28.

Reticulatasporites Leschik, 1958, Beih. Geol. Jb., vol. 31, p. 83.

Type species.—*Reticulatasporites densus* Leschik, 1955.

Description.—Alete iso or microspores; shape more or less spherical. Exine moderate to thick-walled. No tetrad scar present.

Differential diagnosis.—The reticulate sculpture and the absence of a tetrad mark separate this genus from other similar genera.

Botanical affinities.—Unknown.

Reticulatasporites cristatus Stanley, n. sp.

Pl. 36, figs. 1-6

Holotype.—Slide SCB 11-11; location 29.2 $\times$ 106.2; Pl. 36, figs. 1-2.

Isotype.—Slide S-8-2-8; location 35.5 $\times$ 93.0; Pl. 36, figs. 5-6.

Type locality.—Crow Butte, Harding Co., South Dakota.

Type horizon.—Hell Creek formation, Maestrichtian.

Name derivation.—*Crista*=tuft, comb; after the sculpturing characteristic of the species.

Description.—Inaperturate iso or microspore; shape approximately spherical; size, exclusive of ornamentation, 40-53 μ . Exine 2 μ thick; sculpture consists of anastomosing cristae forming a dense reticulum; crista length about 5 μ ; lumen width 3-4 μ .

Differential diagnosis.—The two species that Leschik described and assigned to *Reticulatisporites* are from an upper Triassic horizon and are markedly different from *R. cristatus*, n. sp. The species that is morphologically similar to the above described species is *R. intergranulatus* (Potonie), n. comb. The latter species is smaller in size and has decidedly larger lumina.

Occurrence.—*Reticulatisporites cristatus*, n. sp. was found to be restricted to the Crow Butte section.

Frequency.—"Infrequent" to "common."

Genus **SCHIZOSPORIS** Cookson and Dettmann, 1959

Schizosporis Cookson and Dettmann, 1959, Micropaleont, vol. 5, no. 2, p. 213.

Type species.—*Schizosporis reticulatus* Cookson and Dettmann, 1959.

Description.—Inaperturate pollen grains (?); grains slightly to markedly split, along what appears to be an obscure, predetermined line, into two equal attached parts. Exine moderate to thick; sculpture and structure simple to complicated.

Differential diagnosis.—*Schizosporis* Cookson and Dettmann somewhat resembles *Ovoidites* Potonie but is distinguished from it by its more or less spherical to spheroidal rather than its distinctly fusiform shape.

Botanical affinities.—Cookson and Dettmann (1959, p. 216) stated that *Schizosporis* resembles the pollen of *Rapatea spectabilis* Pilger and *Cephalostemon angustatus* Malme.

Schizosporis complexus Stanley, n. sp.

Pl. 36, figs. 7-17

Holotype.—Slide SCB 11-6; location 35.9 $\times$ 94.1; Pl. 36, figs. 7-9.

Isotype.—Slide SCB 11-4; location 36.4 $\times$ 95.7; Pl. 36, figs. 10-12

Type locality.—Crow Butte, Harding Co., South Dakota.

Type horizon.—Hell Creek formation, Maestrichtian.

Name derivation.—*Complexus*=complex; after the complex ectexine structure present in this species.

Description.—Inaperturate pollen grains (?); shape spherical to subspherical; maximal diameter 36-60 μ . Endexine 1 μ thick; ectexine reticulate with lumina 3 μ wide, muri duplibaculate in construction. A fissure or tear, which is characteristic of the genus, is typically present.

Differential diagnosis.—This species superficially resembles *Schizosporis reticulatus* Cookson and Dettmann. However, *S. reticulatus* is considerably larger in size and is not known to have the complicated duplibaculate muri found in this new species.

Occurrence.—This species was observed in samples from throughout most of the Crow Butte section.

Frequency.—"Common" to "abundant."

***Schizosporis laevigatus* Stanley, n. sp.** Pl. 23, figs. 6-7, Pl. 37, figs. 4-5

Holotype.—Slide G 10-4-3; location 34.1 $\times$ 96.1; Pl. 37, figs. 4-5,

Isotype.—Slide 18-2-12; location 27.5 $\times$ 102.1; Pl. 23, fig. 6.

Type locality.—North Cave Hills, Harding Co., South Dakota.

Name derivation.—*Laevigatus*=smooth; after the smooth exine of members of this species.

Description.—Inaperturate pollen grains (?); outline more or less elliptical with a maximal diameter of 75-100 μ . Exine 1 μ thick, appears to be one layered and smooth. The characteristic tear is present but usually is represented by a fine line with no marked separation between the halves of the grain.

Differential diagnosis.—*Schizosporis laevigatus*, n. sp. somewhat resembles *S. parvus* Cookson and Dettmann but is differentiated from this species by its apparently one layered exine which is decidedly thinner. *S. laevigatus*, n. sp. also resembles a new genus and species described from the Devonian of Oklahoma by Wilson and Urban (1963, p. 16) as *Quisquilites buckhornensis*. This latter species, however, is characterized by a three layered, thick exine that bears cylindrical perforations.

Occurrence.—*Schizosporis laevigatus*, n. sp. was found to occur only in sample 18-2 of the Cannonball member, Fort Union forma-

tion and also in the upper part of Zone I of the North Cave Hills section and in the upper part of the Twin Butte section.

Frequency.—"Infrequent."

Schizosporis microfoveatus Stanley, n. sp.

Pl. 37, figs. 1-3

Holotype.—Slide SCB 11-11; location 36.9×102.1 ; Pl. 37, figs. 1-2.

Isotype.—Slide SCB 11-7; location 34.4×111.2 ; Pl. 37, fig. 3.

Type locality.—Crow Butte, Harding Co., South Dakota.

Type horizon.—Hell Creek formation, Maestrichtian.

Name derivation.—*Micro*=small; *fovea*=pit; after the finely pitted exine characteristic of this species.

Description.—Inaperturate pollen grains (?); shape spheroidal with a maximal diameter of $40-70 \mu$. Exine two layered with endexine approximately 0.5μ thick and ectexine 1μ thick; ectexine finely pitted with lumina being on the order of 0.3μ in diameter. The characteristic tear dividing the grain into two halves is present. In this species the tear almost cuts the grain in half.

Differential diagnosis.—The finely pitted nature of the exine clearly separates *Schizosporis microfoveatus*, n. sp. from other presently described species.

Occurrence.—*Schizosporis microfoveatus*, n. sp. was observed only in samples from Zone II of the Crow Butte section.

Frequency.—"Infrequent."

Schizosporis scabratus Stanley, n. sp.

Pl. 35, figs. 10-17

Holotype.—Slide SCB 11-11; location 45.5×102.2 ; Pl. 35, figs. 10-11.

Isotype.—Slide SCB 12-4; location 35.1×106.0 ; Pl. 35, figs. 16-17.

Type locality.—Crow Butte, Harding Co., South Dakota.

Type horizon.—Hell Creek formation, Maestrichtian.

Name derivation.—*Scabrum*=rough; after the finely granular or rough nature of the exine.

Description.—Inaperturate pollen grains (?); shape spheroidal with a diameter of $15-40 \mu$. Exine scabrate; thickness varies between $1-2 \mu$ (in some cases even on a single specimen). The characteristic

tear dividing the grain into almost two nearly equal halves is present.

Differential diagnosis.—The scabrate exine and the small size differentiate this species from *S. parvus* Cookson and Dettmann.

Occurrence.—*Schizosporis scabratus*, n. sp. was found to be present in all zones of the Crow Butte section.

Frequency.—"Infrequent."

Class GYMNOSPERMAE

Order CYCADALES

Family CYCADACEAE (Provisional assignment)

Genus **CYCADOPITES** Wodehouse ex Wilson and Webster, 1946

Cycadopites Wodehouse, 1933, Bull. Torrey Bot. Club, vol. 60, p. 483.

Cycadopites Wodehouse ex Wilson and Webster, 1946, Amer. Jour. Bot., vol. 33, p. 274.

Monocolpites van der Hammen, 1956, Boletín Geológico, Bogota, vol. 4, Nos. 2-3, p. 82, (in part).

Cycadopites Wodehouse ex Wilson and Webster, Potonie, 1958, Beih. Geol. Jb., vol. 31, p. 92.

Type species.—*Cycadopites folliculus* Wilson and Webster, 1946.

Description.—Monocolpate pollen grains, shape more or less fusiform, size variable. Exine thickness moderate, ornamentation wanting or weakly developed. Sulcus length equals that of grain; sulcus characteristically with ends open and central region touching or overlapping.

Differential diagnosis.—This genus is differentiated from other similar genera by its open ends and its centrally overlapping sulcus.

Botanical affinities.—Cycadaceae?

Cycadopites giganteus Stanley, n. sp.

Pl. 37, figs. 6-9

Holotype.—Slide SCB 11-8; location 37.9×111.1 ; Pl. 37, figs. 6-7.

Isotype.—Slide 8-1a-2; location 42.4×110.4 ; Pl. 37, fig. 9.

Type locality.—Crow Butte, Harding Co., South Dakota.

Type horizon.—Hell Creek formation, Maestrichtian.

Name derivation.—*Giganteus*=large; after the large size of specimens of this species.

Description.—Monocolpate pollen grains; shape more or less fusiform; length $50-72 \mu$, maximum width $15-20 \mu$. Exine psilate,

thickness approximately $1.5\ \mu$. Sulcus overlapping in center with ends of sulcus open; sulcus length equals that of grain.

Differential diagnosis.—*Cycadopites giganteus*, n. sp. is differentiated from *C. pollicularis* Wilson and Webster chiefly on the basis of size.

Occurrence.—This species was observed to be present in samples from Zones I and II of the Crow Butte section.

Frequency.—"Infrequent" to "common."

Cycadopites scabratus Stanley, n. sp.

Pl. 37, figs. 10-15

Holotype.—Slide 18-2-2; location 39.3×112.8 ; Pl. 37, figs. 10-11.

Isotype.—Slide 18-2-1; location 34.3×100.2 ; Pl. 37, figs. 12-13.

Type locality.—Southern half of sec. 24, T. 23 N., R. 9 E., Harding Co., South Dakota.

Type horizon.—Cannonball member, Fort Union formation, Paleocene.

Name derivation.—*Scabrous*=rough; after the roughened nature of the exine common to specimens of the species.

Description.—Monocolpate or sulcate pollen grains; outline more or less ellipsoidal; length $25-35\ \mu$. Exine approximately $0.5\ \mu$ thick, sculpture scabrate. Sulcus long with central portion usually closed or overlapping and one or both ends open.

Differential diagnosis.—*Cycadopites scabratus*, n. sp. is separated from *C. pollicularis* Wilson and Webster (1946) which it slightly resembles, by its smaller size and its scabrous rather than smooth exine.

Occurrence.—*Cycadopites scabratus*, n.sp. was found to occur in the Cannonball member of the Fort Union formation.

Frequency.—"Infrequent."

ORDER CONIFERALES

Family CUPRESSACEAE

Genus THUJA L., 1753

Taxodiceae-pollenites Kremp, 1949, Palaeontographica, vol. 90, pt. B, p. 59. (in part).

Thuja L. (pollen), Pokrovskaja, 1950, Analyse Pollenique, p. 161.

Taxodioidites Pot., Thom. and Thierg., 1950, Geol. Jb., vol. 65, p. 49. (in part).

Thuja L. (pollen), Van Campo, 1953, Trav. Lab. Forest. de Toulouse, vol. 4, art. 3, p. 111.

Thujoites, Zaklinskaia, 1957, Trudy Geol. Inst., No. 6, p. 170.

Taxodiaceapollenites Kremp, Potonie, 1958, Beih. Geol. Jb., vol. 31, p. 78. (in part).

Description.—Inaperturate pollen grains, shape more or less spherical; diameter 25-31 μ . Exine thin and frequently ruptured, sculpture scabrate.

Discussion.—The fossil pollen organ genera listed above in the synonymy are tentatively assigned to the genus *Thuja* for the following reasons:

1) Inasmuch as pollen commonly assigned to *Taxodiaceapollenites* is usually abundant in sediments of Upper Cretaceous and especially Paleocene age in the northern Great Plains, the plant that produced this pollen ought to be also common or at least be present and, furthermore, also have the same stratigraphic range as the pollen. Table 19 lists the plant megafossils found and described by three recent workers in the area, Dorf (1942), Bell (1949) and Brown (1962). Assuming that each of these investigators correctly identified specimens at least to the generic level, one genus, *Thuja*, is outstanding in that it is the only genus that has been found by all three workers in both the Upper Cretaceous and the Paleocene. Plant megafossils of *Taxodium*, to which *Taxodiaceapollenites* is often attributed to is relatively scarce.

2) Macerated pollen grains of *Thuja* commonly have a "fissura" present; those of *Taxodium* usually do not.

3) A ligula is present in *Taxodium* pollen but is absent in pollen of *Thuja* and also in the *Pollenites hiatus* type pollen (see the original description of Potonie).

The arguments against the assignment made here are as follows:

1) The sculpture of the fossil pollen herein tentatively assigned to *Thuja* differs from the sculpture of the pollen of extant *Thuja*. It might also be mentioned that the sculpture of the fossil pollen differs from that of *Taxodium*.

2) Perhaps the strongest argument against an assignment to *Thuja* is that no seeds or cones of this plant have been found in the Rocky Mountain area. As abundant as the fossil pollen under dis-

cussion is, especially in the Paleocene, one would expect to find these types of megafossil remains. It is for this reason that the question mark is inserted between the generic and trivial names of the species assigned to *Thuja* in this work.

Finally, it should be mentioned that Zaklinskaia (1957, p. 170) arrived at a similar conclusion by assigning *T. hiatus* and related forms to *Thujoites* sp.

Differential diagnosis.—*Thuja* pollen is separated from other Taxodiaceae-Cupressaceae pollen described in this paper by lacking a distinct ligula.

Distributions.—*Thuja* L. is presently confined to the eastern coasts of both the United States and China.

***Thuja ? hiatus* (Potonie), n. comb.**

Pl. 38, Figs. 1-3

- Pollenites hiatus* Potonie, 1931, Jb. preuss. geol. L.-A., vol. 52, p. 5, fig. 27.
Pollenites hiatus Potonie, Potonie, 1933, Arb. Inst. Palaeobot., vol. 4, p. 27, pl. 1, fig. 30; pl. 6, fig. 4.
Taxodium hiatipites Wodehouse, 1933, Bull. Torrey Bot. Club, vol. 60, p. 493, fig. 19 (not fig. 17 as given).
Pollenites hiatus Potonie, Wolf, 1934, Arb. Inst. Palaeobot., vol. 5, p. 69, pl. 5, fig. 29.
Pollenites hiatus Potonie, Raatz, 1937, Abb. preuss. Geol. L.-A.N.F., No. 183, p. 14.
Pollenites hiatus Potonie, Thiergart, 1940, Brenn. Geol., No. 13, p. 30, pl. 2, fig. 10; pl. 4, fig. 8; pl. 5, fig. 4; pl. 10, fig. 8.
Taxodium hiatipites Wodehouse, Wilson and Webster, 1946, Amer. Jour. Bot., vol. 33, p. 275, fig. 6.
Taxodiaceapollenites hiatus (Potonie), Kremp, 1949, Palaeontographica, vol. 90, pt. B, p. 59.
Taxodoidites hiatus (Potonie), Potonie, Thomson and Thiergart, 1950, Geol. Jb., vol. 65, p. 49, pl. A, fig. 23.
Taxodioipollenites hiatus (Potonie), Potonie, 1951, Palaeontographica, vol. 91, pt. B, p. 143, fig. 17.
Inaperturopollenites hiatus (Potonie), Thomson and Pflug, 1953, Palaeontographica, vol. 94, pt. B, p. 65, pl. 5, figs. 14-20.
Taxodium hiatipites Wodehouse, Rouse, 1957, Canadian Jour. Bot., vol. 35, p. 366, pl. 2, figs. 25 and 26.
Pollenites hiatus Potonie, Kremp, Ames and Grebe, 1957, Cat. Fossil Spores and Pollen, vol. 1, p. 115.
Thujoites sp. (pollen), Zaklinskaia, 1957, Trudy Geol. Inst., S.S.S.R., No. 6, p. 170, pl. 26, figs. 13-15.
Pollenites hiatus Potonie, Kremp and Ames, 1961, Cat. Fossil Spores and Pollen, vol. 14, p. 76a, 76b.
Taxodium hiatipites Wodehouse, Rouse, 1962, Micropaleont., vol. 8, No. 2, p. 201, pl. 2, fig. 4.

Holotype.—Slide 1 V-43d, Potonie, 1931.

Description.—Inaperturate to perhaps aperturate pollen grains (see Kremp, 1949, p. 59) with a diameter of 25-31 μ . Exine approxi-

mately 0.5μ thick with ectexine and endexine about equal in thickness; ectexine scabrate; exine characteristically bears a rupture (fissure).

Differential diagnosis.—*Thuja ? hiatus* (Potonie) is separated from *Sequoiapollenites paleocenicus*, n. sp. by the absence of a distinct ligula.

Occurrence.—*Thuja ? hiatus* (Potonie) was found to occur in almost all samples from all of the Upper Cretaceous and Paleocene sections sampled.

Frequency.—"Infrequent" to "dominant."

Family PINACEAE

PICEA Dietr.

- Piceapollenites* Potonie, 1931, Jb. preuss. Geol. L.-A., vol. 52, p. 3, fig. 31.
Picea Dietr. (pollen), Wodehouse, 1933, Bull. Torrey Bot. Club, vol. 60, p. 488.
Piceapollenites Potonie, Potonie and Venitz, 1934, Arb. Inst. Palaeobot. u. Petrog., vol. 5, p. 18.
Picea Dietr. (pollen), Wodehouse, 1935, Pollen Grains, p. 262.
Picea Dietr. (pollen), Pokrovskaja, 1950, Analyse Pollinique, p. 14-7.
Picea Dietr. (pollen), van Campo-Duplan, 1950, Trav. Lab. Forest. de Toulouse, vol. 4, art. 1, p. 123.
Picea Dietr. (pollen), Zaklinskaia, 1957, Trudy Geol. Inst., S.S.S.R., No. 6, p. 124.
Piceapollenites Potonie, Potonie, 1958, Beih. Geol. Jb., vol. 31, p. 64.
Picea Dietr. (pollen), Beug, 1961, Leitfaden der Pollenbestimmung, pt. 1, p. 12.

Description.—Bisaccate pollen grains, body usually large; in polar view usually oval in outline; cap finely reticulate. Bladders hemicircular, large; proximal root attachment well proximal of body equator.

Discussion.—Two major groups or sections of *Picea* pollen are often recognized by investigators of Recent pollen. One type is called the *Picea*-type (Beug, 1961) or the *Eupicea*-type (Zaklinskaia, 1957) and is characterized by the cap passing more or less smoothly into the proximal roots of the bladders and by its larger size. *Picea abies* would be an example of this type. The other group is called the *Omorica*-type, and it is characterized by a peak or interruption in the transition from the cap to the proximal root region of the bladder and also by its smaller dimensions. *Picea omorica* (Europe

and Asia) or *Picea mariana* (North America) are two examples of the latter group.

Distribution.—According to Pokrovskaia (1950) the section *Eupicea* has a distribution throughout the Northern Hemisphere. The section *Omorica* is found only in eastern Asia and North America with the exception of *Picea omorica* which is found in eastern Yugoslavia and is considered to be a Tertiary relict. In general, *Picea* is usually found in the cooler regions of the Northern Hemisphere and the encounterance of this pollen in fossil deposits usually suggests the proximity of a cool area.

***Picea rara* Stanley, n. sp.**

Pl. 38, figs. 4-7

Holotype.—Slide 10-4-4S; location 34.2×106.5 ; Pl. 38, fig. 4.

Type locality.—Twin Butte, Harding Co., South Dakota.

Type horizon.—Ludlow member, Fort Union formation, Paleocene.

Name derivation.—*Rarus*=scarce; after the few specimens of this species encountered.

Description.—Bisaccate pollen grain; body laterally elongated with a maximal dimension of $50-60 \mu$. Exine finely punctate with pits having a diameter of about 0.3μ ; ectexine thickness 1μ ; endexine approximately $0.2-0.3 \mu$ thick. Bladders large, thin and bear an infrareticulation with small lumina; proximal bladder attachment of the *Omorica*-type and well proximal of body equator. Furrow thin and is ornamented by a fine reticulation.

Differential diagnosis.—The relatively large size of specimens of this species as well as the bladders to body attachment separate this species from the other species of bisaccate pollen described in this paper.

Occurrence.—*Picea rara*, n. sp. was found to occur in samples from the Twin Butte section, the Cannonball section and in Zone I of the North Cave Hills section.

Frequency.—"Infrequent."

Genus **PINUS** (Tourn.), L., 1753

Pinus (Tourn.), L. (pollen), Wodehouse, 1933, Bull. Torrey Bot. Club, vol. 60, p. 487.

Pinus (Tourn.), L. (pollen), Rudolph, 1935, Sond. Beih. Bot. Centralbl., vol. 54, pt. B, p. 253.

- Pinus* (Tourn.), L. (pollen), Wodehouse, 1935, Pollen Grains, p. 256.
Pinuspollenites Raatz, 1937, Abb. preuss. Geol. L.-A.N.F., No. 183, p. 15.
Pinus (Tourn.), L. (pollen), Pokrovskaia, 1950, Analyse Pollinique, p. 152.
Pinus (Tourn.), L. (pollen), van Campo-Duplan, 1950, Trav. Lab. Forest. de Toulouse, vol. 4, art. 1, p. 70.
Pinus (Tourin.), L. (pollen), Macko, 1957, Lower Miocene Pollen Flora, p. 22.
Pinus (Tourn.), L. (pollen), Zaklinskaia, 1957, Trudy Geol. Inst., S.S.S.R., No. 6, p. 138.
Pinuspollenites Raatz, Potonie, 1958, Beih. Geol. Jb., vol. 31, p. 62.
Pinus (Tourn.), L. (pollen), Pla, 1961, Polen, p. 155.
Pinus (Tourn.), L. (pollen), Beug, 1961, Leitfaden der Polenbestimmung, pt. 1, p. 12.

Description.—Disaccate pollen grains; body circular to ovaloid; cap moderately reticulate; comb may or may not be present. Air bladders more or less of circular or hemicircular in polar view; reticulation coarse; proximal attachment of bladder to body is near, or slightly distal of body equator. Overall size (after Pokrovskaia) is between 60 and 105 μ .

Discussion.—In 1935 Rudolph recognized two basic types of pollen grains found in the genus *Pinus*. One type has bladders that are hemicircular in polar view whereas the other type has bladders which, in polar view, are greater than hemicircular. The pollen grains with the hemicircular bladders were found by Rudolph to be restricted to the subgenus *Hapoxylon* (sections *Cembra*, *Paracembra* and *Strobis*) and, therefore, he called this type of pollen the *Hapoxylon*-type. Pine pollen grains with greater than hemicircular bladders were found by Rudolph to occur in all the species of the subgenus *Diploxylon* as well as some of the species of the subgenus *Hapoxylon* he investigated. This latter type of pollen Rudolph called the *Sylvestris*-type. It is typical of *Pinus sylvestris* and is not restricted to the subgenus *Diploxylon*.

Subdividing pine pollen into the two groups discussed above has some usefulness. However, it must be mentioned that in many cases if the grain is an equatorial or oblique orientation it may be impossible to assign it to one of the two groups. In this study it was found that pollen of the *Hapoxylon*-type occurs in greater numbers whereas the pollen of the *Sylvestris*-type is not so abundant and is also stratigraphically restricted.

Differential diagnosis.—The size of the pollen grain, the cap reticulation, and most importantly, the location of the bladder-

body contact position of the proximal root separate pine pollen from other disaccate pollen species.

Pinus ruginosa Stanley, n. sp.

Pl. 39, figs. 1-7

Holotype.—Slide S-8-2-8; location 42.1×99.0 ; Pl. 39, figs. 1-2.

Isotype.—Slide SCB 11-9; location 38.0×109.2 ; Pl. 39; figs. 5-6.

Type locality.—Crow Butte, Harding Co., South Dakota.

Type horizon.—Hell Creek formation, Maestrichtian.

Name derivation.—*Ruginosus*=wrinkled; after the wrinkled nature of the bladders.

Description.—Disaccate pollen grains, body distinctly ovaloid with major axis being the body length; body length $36\text{--}45\ \mu$. Cap finely to moderately reticulate; ectexine of cap about $1.5\ \mu$ thick whereas endexine of cap approximately $0.5\ \mu$ thick. Bladders of the *Sylvestris*-type, thin-walled and usually wrinkled; bladders are always small in relation to the body size. Furrow usually wide and appears to lack sculpturing.

Differential diagnosis.—The relatively large wrinkled bladders separate *Pinus ruginosa*, n. sp. from the other species assigned to the genus *Pinus*.

Occurrence.—*Pinus ruginosa*, n. sp. was found to occur in samples from Zone I and Zone II of the Crow Butte section.

Frequency.—"Infrequent."

Pinus semicircularis Stanley, n. sp.

Pl. 39, figs. 8-10; Pl. 40, figs. 1-7

Holotype.—Slide 18-3-2; location 37.2×100.2 ; Pl. 40, figs. 1-3.

Isotype.—Slide 18-3-1; location 32.3×108.8 ; Pl. 39, figs. 8-10.

Type locality.—Southern half of sec. 24, T. 23 N., R. 9 E., Harding Co., South Dakota.

Type horizons.—Cannonball member, Fort Union formation, Paleocene.

Name derivation.—*Semi*=half; *circulus*=circle; after the *Hapoxylon* nature of the bladders.

Description.—Disaccate pollen grain; body circular to more or less elliptical in outline; size $30 \times 36\ \mu$; cap sculpture finely reticulate with lumina about $0.5\ \mu$ in diameter; ectexine $1.5\ \mu$ thick

whereas endexine is approximately $0.5\ \mu$ thick. Bladders *Hapoxylon* type, moderately infrareticulate; overall length of grain $40\text{--}60\ \mu$.

Differential diagnosis.—The *Hapoxylon* type bladders readily separate this species from the other species herein assigned to the genus *Pinus*.

Occurrence.—*Pinus semicircularis*, n. sp. was found to occur in most of the samples from the North Cave Hills, Twin Butte, and Cannonball sections.

Family **PINACEAE** (Provisional assignment)

Genus **LARICOIDITES** Potonie, 1958

Laricoidites Potonie, Thomson and Thiergart, 1950, Geol. Jb., vol. 65, p. 48.
Inaperturopollenites Pflug and Thomson in Thomson and Pflug, 1953, Palaeontographica, vol. 94, pt. 31, p. 64.

Laricoidites Potonie, Thomson and Thiergart ex Potonie, 1958, Beih. Geol. Jb., vol. 31, p. 76.

Type species.—*Laricoidites magnus* (Potonie), Potonie, 1958.

Description.—Inaperturate pollen grains; shape more or less spherical with many secondary folds. Size large, i.e. 50 to perhaps over $100\ \mu$. Exine thin, smooth to infra-scabrate.

Discussion.—In the writer's opinion the name *Laricoidites* was not validly published until 1958. At that time Potonie gave a clear definition of the genus and clearly separated the larger inaperturate pollen from *Inaperturopollenites* Pflug and Thomson.

Differential diagnosis.—*Laricoidites* is artificially separated from *Inaperturopollenites* on the basis of its larger size.

Botanical affinities.—*Larix*??

Laricoidites magnus (Potonie), Potonie, Thomson and Thiergart

Pl. 40, figs. 8-9

Sporonites (?) *magnus* Potonie, 1931, Z. Braunkohle, vol. 27, p. 556, fig. 6.

Pollenites magnus (Potonie), Potonie, 1934, Arb. Inst. Palaeont., vol. 4, p. 48, p. 6, fig. 5.

Pollenites magnus (Potonie), Potonie, 1934, Arb. Inst. Palaeont., vol. 5, p. 16, pl. 1, fig. 19.

Larix-pollenites magnus (Potonie), Raatz, 1937, Abb. preuss. geol. L.-A.N.F., No. 183, p. 15.

Laricoidites magnus (Potonie), Potonie, Thomson and Thiergart, 1950, Geol. Jb., vol. 65, p. 48, pl. C, figs. 9, 10.

Inaperturopollenites magnus (Potonie), Thomson and Pflug, 1953, Palaeontographica, vol. 94, pt. B, p. 64, pl. 4, figs. 83-88.

Sporonites (?) *magnus* Potonie in Kremp. Ames and Kovar, 1958, Catalog Fossil Spores and Pollen, vol. 4, p. 110.

- Pollenites magnus* (Potonie), Potonie in Kremp and Ames, 1962, Catalog Fossil Spores and Pollen, vol. 14, p. 77a, b.
Inaperturopollenites cf. *magnus* (Potonie), Thomson and Pflug, Manum, 1962, Norsk Polarinstitut, No. 125, p. 39.

Holotype.—Plate 4, figs. 6, Potonie, 1931, (?).

Description.—Inaperturate pollen grains; shape more or less spherical with specimens usually always badly folded; diameter on the order of 100 μ . Exine about 1.2 μ thick with the ectexine approximately twice the thickness of the endexine. A faintly developed scabrate sculpturing is present.

Differential diagnosis.—The large size, the weakly developed scabrate sculpturing and the two-layered exine separate this species from similar species.

Occurrence.—*Laricoidites magnus* (Potonie), Potonie, Thomson and Thiergart was found to occur only in samples from the Cannonball member of the Fort Union formation.

Frequency: "Infrequent."

Family **PODOCARPACEAE**

Genus **PODOCARPUS** L'Herit, 1807

- Podocarpus* L'Herit (pollen), Wodehouse, 1935, Pollen Grains, p. 273.
Podocarpus L'Herit (pollen), Pokrovskaja, 1950, Analyse Pollinique, p. 138.
Podocarpus L'Herit (pollen), Zaklinskaia, 1957, Trudy Geol. Inst., S.S.S.R., No. 6, p. 98.
Podocarpus L'Herit (pollen), Martin, 1959, Grana Palynologica, vol. 2, No. 1, p. 40.
Podocarpus L'Herit (pollen), Maliavkinavar in Samoilovitch, et al., 1961, Pollen and Spores from Western Siberia, p. 127.

Description.—Disaccate pollen grains; body more or less circular to perhaps angular in dorso-ventral view; cap is often heavily ornamented with sinuous muronate elements. Air bladders often delicate and fragile, perhaps large in relation to the body but not necessarily so; infrareticulation moderate; in distal root area the infrareticulation is frequently linear with the lumina oriented at right angles to the furrow orientation. Furrow distinct and usually wide; the boundary between the furrow and the bladders is sharp.

Discussion.—Pollen similar to that produced by the genus *Podocarpus* has been found in Mesozoic and Tertiary sediments of the Northern Hemisphere in both Europe (including Siberia) and North America by Thiergart (1940), Zaklinskaia (1957), Bolkhovi-

tina (1953, 1956, 1959), Anderson (1960), Simpson (1961), Pierce (1961), and others. Plant megafossils of the genus are relatively rare. To this writer's best knowledge there is no known recent paper that assigns plant megafossils from the Northern Hemisphere to the genus *Podocarpus*. Florin (1958, p. 408) stated that "the alleged occurrences of podocarps in Mesozoic and Tertiary deposits in the Northern Hemisphere should in my opinion be regarded with scepticism." The characteristics of *Podocarpus* pollen have been discussed in some detail by many workers and the pollen grains of the extant species of *Podocarpus* are distinctive. It should be pointed out that Zaklinskaia (1957, p. 99) mentioned that fossil podocarpaceous pollen grains deviate from the norm for that of extant pollen. This is what one would normally expect. This in itself presents no real problem. The major problem is the lack or absence of plant megafossils. One might rationalize himself out of this problem by saying that members of the genus were restricted to the higher elevations and subsequently not preserved as fossils. This is avoiding the problem rather than solving it. In the South Dakota area the pollen herein assigned to the extant genus *Podocarpus* restricted to a relatively narrow stratigraphic horizon. Because of this and because of its apparently wide-spread distribution, it is one of the more important guide fossils. Theoretically, the podocarpaceous plant megafossils, might also be restricted to this narrow zone and unless one knew where to look he might overlook this zone in sampling for plant megafossils.

Differential diagnosis.—Some of the more important criteria for separating pollen grains of *Podocarpus* from those of the *Pinaceae* are thin, usually wrinkled bladders that often have linearly aligned lumina on the distal root area, a coarsely ornamented cap, and a furrow that is sharply separated from the bladders. The criterion of large bladders relative to body size is a poor one inasmuch as this relationship is not present in many species. For example, *Podocarpus glomeratus*, *P. macrophylla*, *P. sprucei*, *P. nagi*, and *P. reichei* all have a bladder size to body size ratio about like that found in some species of *Pinus*.

Distribution.—A family that at present is confined to the Southern Hemisphere although at least one species, *Podocarpus reichei* is found as far north as northern Mexico.

Podocarpus maximus Stanley, n. sp.

Pl. 41, figs. 1-8

Holotype.—Slide 18-3-2; location 27.3×102.4 ; Pl. 41, figs. 2-4.

Isotype.—Slide 18-2-10, location 29.6×101.2 ; Pl. 41, figs. 5-6.

Type locality.—Southern half of sec. 24, T. 23 N., R. 9 E, Harding County, South Dakota.

Type horizon.—Cannonball member, Fort Union formation; Paleocene.

Name derivation.—*Maximus*=greatest; this species is of great value in resolving some of the problems of correlation.

Description.—Disaccate pollen grains; body outline more or less circular with a diameter of $22-30 \mu$; cap bears vermiculate to granulate sculpture elements that are up to 3μ high in the lateral regions and about $\frac{1}{2}$ that thickness in the polar area. Bladders relatively large and of the *sylvestris*-type; infrareticulation moderate in size and tends to be radially aligned, outward from the distal root area of the bladder. Furrow more or less narrow and appears to lack ornamentation.

Differential diagnosis.—The cap sculpture and the linearly oriented lumina on the distal root area of the bladders readily separate this species from those assigned to *Pinus*.

Occurrence.—This species was found to occur in samples from the middle part of Zone I of the North Cave Hills section, in most of the samples from the Twin Butte section and in samples from the Cannonball section.

Frequency.—"Infrequent."

Family **TAXODIACEAE** (Provisional assignment)

SEQUIAPOLLENITES Thiergart, 1938

Sequoiapollenites Thiergart, 1938, Jb. Preuss. geol. L.-A., vol. 58, p. 301.

Sequoioidites Potonie, Thomson and Thiergart, 1950, Geol. Jb., vol. 65, p. 49.

Sequoiapollenites Thiergart, Potonie, 1958, Beih. Geol. Jb., vol. 31, p. 79.

Type species.—*Sequoiapollenites polyformosus* Thiergart, 1938, p. 301, pl. 23, fig. 6.

Description.—Inaperturate pollen grains; shape more or less spherical; exine scabrate. A distinct ligula is present.

Discussion.—A single species of a taxodiaceous pollen grain is described and assigned to this artificial genus mainly because it

TABLE 19

DISTRIBUTION OF PLANT MEGAFOSSILS REPRESENTING
THE TAXODIACEAE AND CUPRESSACEAE IN THE UPPER
CRETACEOUS AND PALEOCENE

Taxodiaceae	Upper Cretaceous	Paleocene	Ligula
<i>Cryptomaria</i>	Be	Be	+
<i>Glyptostrobus</i>	Br	Br	+
<i>Metasequoia</i>	Br	Br	+
<i>Sequoia</i>	D, Be	D, Be	+
<i>Taxodium</i>	Br, D?	Br, D?	+
Cupressaceae			
<i>Fokienia</i>		Br	0
<i>Thuja</i>	Br, D, Be	Br, D, Be	0

Be=Bell, 1949
Br=Brown, 1962
D=Dorf, 1942

could be one of several genera that produce more or less similar pollen grains. In other words in this case this writer is considerably less sure of the natural affinity of these pollen grains than he was in the case of grains assigned to *Thuja*. One could say that of all the taxodiaceous genera listed in Table 19, the genus *Sequoia* is the most likely candidate for being the parent plant that produced pollen described here as *Sequoiapollenites*. It is the only taxodiaceous genus of which megafossil remains were definitely identified by at least two workers.

Differential diagnosis.—*Sequoiapollenites* is separated from other similar genera by its short but broad ligula (see Potonie, 1958, p. 79).

Botanical affinities.—Taxodiaceae; possibly *Sequoia* (see discussion above).

***Sequoiapollenites paleocenicus* Stanley, n. sp.**

Pl. 38, figs. 8-11

Holotype.—Slide 18-4-7; location 40.9×112.3 ; Pl. 38, fig. 8.

Isotype.—Slide 18-4-15; location 26.9×103.2 ; Pl. 38, fig. 11.

Type locality.—Southern half of sec. 24, T. 23 N., R. 9 E., Harding Co., South Dakota.

Type horizon.—Cannonball member, Fort Union formation, Paleocene.

Name derivation.—Named because of its occurrence in Paleocene sediments.

Description.—Inaperturate pollen grains; shape more or less spherical with a diameter of 20-30 μ . Exine about 0.5 μ thick with both endexine and ectexine approximately of equal thickness; ectexine sculpture scabrate; in germinal region, ectexine appears to be absent. Ligula bent, approximately 6 μ long and 3 μ wide; a distal pore can sometimes be observed on the ligula.

Differential diagnosis.—This species is separated from *Thuja* ? *hiatus* by the presence of a ligula. *Sequoiapollenites polyformosus* Thiergart is slightly to moderately larger in size and also lacks the unsculptured area around the germinal region. *Sequoiapollenites* sp. Manum is similar in that, after figure 11a (Manum, 1962), it appears to lack sculpturing in the germinal region. The species described by Manum is generally larger in size and has a short, usually unbent ligula.

Occurrence.—This species was found to occur in samples from the Cannonball section and also in samples from the upper part of Zone I of the North Cave Hills section.

Frequency.—"Infrequent."

Order GNETALES

Family EPHEDRACEAE

Genus EPHEDRA Tourn. ex L. 1737

- Ephedra* Tourn. ex L. (pollen), Wodehouse, 1933, Bull. Torrey Bot. Club, vol. 60, p. 496.
Ephedra Tourn. ex L. (pollen), Wodehouse, 1934, Torrey, vol. 34, p. 1.
Ephedra Tourn. ex L. (pollen), Wodehouse, 1935, Pollen Grains, p. 288.
Equisetospores Daugherty, 1941, Carnegie Inst. Washington Pub. 526, p. 63.
Ephedra Tourn. ex L. (pollen), Pokrovskaja, 1950, Analyse Pollinique, p. 162.
Ephedripites Bolkhovitina, 1953, Trudy Inst. Geol. Nauk AN S.S.S.R., No. 145, Geol. Ser. no. 61, p. 60.
Ephedra Tourn. ex L. (pollen), Tchigouriaeva, 1954, Grana Palynologica, vol. 1, no. 1, p. 95.
Ephedra Tourn. ex L. (pollen), Beug, 1956, Die Naturwissenschaften, vol. 43, p. 332.
Ephedra Tourn. ex L. (pollen), Cookson, 1956, Nature, vol. 177, p. 47.
Equisetospores Daugherty, Potonie, 1956, Beih. Geol. Jb., vol. 23, p. 57.
Ephedra Tourn. ex L. Zaklinskaia, 1957, Trudy Geol. Inst. S.S.S.R., No. 6, p. 175.
Ephedripites Bolkhovitina, Potonie, 1958, Beih. Geol. Jb., vol. 31, p. 88.
Ephedra Tourn. ex L. (pollen), Steeves and Barghoorn, 1959, Jour. Arnold Arboretum, vol. 40, No. 3, p. 221.
Ephedra Tourn. ex L. (pollen), Wilson, 1959, Oklahoma Geol. Notes, vol. 19, No. 2, p. 35.

- Ephedra* Tourn. ex L. (pollen), Scott, 1960, Micropaleont., vol. 6, No. 3, p. 271.
Equisetospores Daugherty, Potonie, 1960, Beih. Geol. Jb., vol. 39, p. 53.
Ephedripites Bolkhovitina, Ames, 1962, Translations, Catalog Fossil Spores and Pollen, vol. 2, p. 67.
Ephedripites Bolkhovitina, Wilson, 1962, Oklahoma Geol. Sur. Circ. No. 49, p. 31.

Description.—Prolate inaperturate pollen grains which usually bear many ridges that are oriented more or less parallel to the long axis. Some species of fossil and Recent *Ephedra* have vestigial sack-like structures at each end.

Discussion.—A detailed study has been made by Steeves and Barghoorn (1959) on many extant and one fossil species of *Ephedra*. In this work, they divided the extant species of *Ephedra* into four morphological groups. Unfortunately, *Ephedra voluta*, n. sp. does not fit well into any of these groups. For a good summary of the genus along with related genera, the reader is referred to Wilson (1959) and Scott (1960).

Differential diagnosis.—*Ephedra* pollen can occasionally be confused with pollen of *Welwitschia* (see Beug, 1956, p. 333). Also some species of *Ephedra* pollen (including the new species described herein) closely resemble spores of *Schizaea* (see Bolkhovitina, 1961, pl. 6, figs. 1-3). The presence or absence of a monolete mark should determine to which of these genera a particular specimen belongs.

***Ephedra voluta* Stanley, n. sp.**

Pl. 40, figs. 10-11

Holotype.—Slide CBO-7; location 34.6×106.7 ; Pl. 40, fig. 10.

Type locality.—Crow Butte, Harding Co., South Dakota.

Type horizon.—Hell Creek formation, Maestrichtian.

Name derivation.—*Voluta*=turn round; after the ridges or muri which are turned back or around.

Description.—Inaperturate ellipsoidal pollen grains; length about 48μ , width of grain about 24μ . Ektexine sculpture consists of about three low wide ridges that cut across the grain at a sharp angle and at each end are looped backwards thereby producing six muri that cross the grain; muri about 3μ wide in central portion and thin to about 1 to 1.5μ at the ends where they are turned back forming a "U". Spaces between ridges are on the order of 1μ wide. Endexine thin.

Differential diagnosis.—*Ephedra voluta*, n. sp. somewhat resembles some of the specimens of *Ephedra chinleana* (Daugherty), Scott, 1960 (especially pl. 1, fig. 11). However, in *E. voluta*, n. sp., there is no fusion of the muri but all the muri are turned back.

Occurrence.—*Ephedra voluta*, n. sp. was found to occur in samples from the lowermost part of Zone III of the Crow Butte section and also in samples from the Cannonball member of the Fort Union formation.

Frequency.—"Infrequent."

Class ANGIOSPERMAE

Family ANACARDIACEAE (Provisional assignment)

Genus RHOIPITES Wodehouse, 1933

Rhoipites Wodehouse, 1933, Bull. Torrey Bot. Club, vol. 60, p. 513.

Rhoidites Erdtman, 1947, Svensk Bot. Tidskrift, vol. 41, No. 1, p. 710.

Rhoidites Potonie, Thomson and Thiergart, 1950, Geol. Jb., vol. 65, p. 57.

Rhoipollenites Potonie, 1951, Palaeontographica, vol. 91, pt. B, p. 146.

Tricolporopollenites Pflug (in part), in Thomson and Pflug, 1953, Palaeontographica, vol. 94, pt. B, p. 98.

Rhoipites Wodehouse, Potonie, 1960, Beih. Geol. Jb., vol. 39, p. 100.

Type species.—*Rhoipites bradleyi* Wodehouse, 1933.

Description.—Prolate tricolporate pollen grains. Exine reticulate, colpi long and infolded. Pores more or less circular to equatorially elongated (Wodehouse compares the type species with *Rhus* pollen).

Differential diagnosis.—The infolded colpi and the equatorially elongated pores separate this species from *Caprifoliipites* Wodehouse.

Botanical affinities.—Anacardiaceae?

***Rhoipites crassus* Stanley, n. sp.**

Pl. 41, figs. 9-11

Holotype.—Slide 1-12 BB; location 20.0 × 98.2; Pl. 41, figs. 9-11.

Type locality.—North Cave Hills, Harding Co., South Dakota.

Type horizon.—Ludlow member, Fort Union formation, Paleocene.

Name derivation.—*Crassus*=thick, fat; after the thick exine which is characteristic of this species.

Description.—Prolate tricolporate grains; length of polar axis 38-45 μ ; diameter 28-34 μ ; shape-class-index about 1.3. Endexine 1.5 μ thick; ectexine scabrate with a thickness of approximately 2 μ . Colpi long, straight, and closed; caverna distinct; apocolpium moderate. Pores more or less circular to equatorially elongated with a diameter of 3 μ .

Differential diagnosis.—*Rhoipites crassus*, n. sp. is differentiated from *Pollenites megadolium* Potonie and *P. pseudocingulum* Potonie by its considerably thicker exine.

Occurrence.—*Rhoipites crassus*, n. sp. was found to occur in samples from the middle part of Zone I of the North Cave Hills section.

Frequency.—"Infrequent."

Botanical affinities.—"Unknown."

Rhoipites globosus Stanley, n. sp.

Pl. 42, figs. 1-13

Holotype.—Slide SCB-11-9, location 30.2 $\times$ 92.9; Pl. 42, figs. 1-3.

Isotype.—Slide SCB-11-5; location 29.3 $\times$ 109.8; Pl. 42, figs. 7-9.

Type locality.—Crow Butte, Harding Co., South Dakota.

Type horizon.—Hell Creek formation; Maestrichtian.

Name derivation.—*Globus*=ball; after the football-like (American) outline of specimens of this species.

Description.—Prolate tricolporate pollen grains; shape index 1.1-1.2; length polar axis 17-20 μ , equatorial axis 14-18 μ . Endexine less than 0.5 μ thick; ectexine sculpture elements muri forming a fine reticulum with lumina having a diameter of approximately 0.5 μ ; muri height about 1 μ . Colpi long, straight, invaginated; floor of colpus slightly darker due to perhaps a thicker membrane; apocolpium very small. Pores equatorially directed with a size of about 3 - 5 μ .

Differential diagnosis.—*Rhoipites globosus*, n. sp. is separated from other similar species by its characteristic shape and size.

Occurrence.—*Rhoipites globosus*, n. sp. was observed to occur only in samples from the Crow Butte section.

Frequency.—"Infrequent."

Rhoipites pisinnus Stanley, n. sp.

Pl. 42, figs. 14-23

Holotype.—Slide SCBO-6; location 34.7 $\times$ 109.5; Pl. 42, figs. 17-22.

Isotypes.—Slide SCBO-6; location 37.2×96.8 ; Pl. 42, figs. 14-16.

Type locality.—Crow Butte, Harding Co., South Dakota.

Type horizon.—Hell Creek formation, Maestrichtian.

Name derivation.—*Pisinnus*=small, little; after the small size of this species of *Rhoipites*.

Description.—Prolate tricolporate pollen grain; length of polar axis 15-19 μ ; diameter 14-16 μ ; shape shape-class-index about 1.2. Endexine approximately 0.5 μ thick whereas ectexine about 1 μ thick. Sculpture faintly reticulate with lumina 0.2-0.3 μ wide. Colpi long, straight and slightly open, apocolpium moderate. Pores 2 to 3 μ long and 1 μ wide. Colpi bear a caverna (Thomson and Pflug, 1953) or costae (Van Campo, 1959, 1961).

Differential diagnosis.—*Rhoipites pisinnus*, n. sp. is differentiated from *Rhoipites pseudocingulum* (Potonie), Potonie by its smaller size. This new species is distinguished from *R. crassus*, n. sp. by its much smaller size and its reticulate exine sculpture.

Occurrence.—This species was found to be present in Zone III of the Crow Butte section and in Zones I and II of the North Cave Hills section.

Frequency.—"Infrequent" to "common."

Family **BETULACEAE**

Genus **ALNUS** (Tourn.) Hill, 1756

Alni-pollenites Potonie, 1931, Jb. Preuss. geol. L.-A., vol. 52, p. 3.

Alni-pollenites Potonie, Potonie, 1934, Arb. Inst. Palaeobot., vol. 4, p. 58.

Alnus Hill (pollen), Wodehouse, 1935, Pollen Grains, p. 369.

Alnuspollenites Raatz, 1937, Abb. Preuss. geol. L.-A.N.F., No. 183, p. 20.

Alnus Hill. (pollen), Thiergart, 1940, Schr. Geb. Brennst.-Geol., pt. 13, p. 41.

Alnus Hill (pollen), Pokrovskaja, 1950, Analyse Pollinique, p. 183.

Alnus Hill. (pollen), Erdtman, 1953, Svensk Bot. Tidsk., vol. 47, pt. 3, p. 449.

Alnus Hill (pollen), Erdtman, 1954, Pollen Analysis, p. 68.

Alnipollenites Potonie, Potonie, 1960, Beih., Geol. Jb., vol. 39, p. 129.

Alnus Hill (pollen), Simpson, 1961, Roy. Soc. Edinburgh, Trans., vol. 64, No. 16, p. 441.

Description.—Oblate polyporate pollen grains; diameter 15-20 μ ; outline in polar view triangular to polygonal depending on pore number; pores equatorial; in extant species pores usually number four to five, rarely three or six; in fossil species, three pores are common. Endexine about 0.5 μ thick whereas ectexine thickness is

on the order of 1 to 1.5 μ ; sculpture scabrate, faintly granulate or short, haphazardly arranged ridges (*A. rubra*); endexinous ridges (arci) always present but may be weakly developed (*A. sinuata*). Pores equatorially or slightly subequatorially located; pore outline elliptical with major axis meridionally directed; labrum formed by exine in pore region (anulus) thickening centrifugally; in some species (*A. glabrata*) a distinct vestibulum is present whereas in other species (*A. crispa*) the vestibulum is poorly developed.

Discussion.—The two new species herein described and assigned to *Alnus* lack the exine stratification found in the pollen of seven extant species of *Alnus* used for comparative purposes. Arci were present in the two fossil species, and on the basis of this, these species are placed in the genus *Alnus*.

Differential diagnosis.—The presence of more or less well-developed arc associated with a distinctly oblate, porate pollen are characteristic of pollen of the genus *Alnus*.

***Alnus quaternaria* Stanley, n. sp.**

Pl. 43, figs. 1-3

Holotype.—Slide S-8-1a-1; location 39.2 $\times$ 112.2; Pl. 43, figs. 1-2.

Isotype.—Slide S-8-1a-1; location 34.9 $\times$ 112.7; Pl. 43, fig. 3.

Type locality.—Crow Butte, Harding Co., South Dakota.

Type horizon.—Hell Creek formation, Maestrichtian.

Name derivation.—*Quattuor*=four; after the four pores which are typical of this species.

Description.—Polyporate oblate pollen grains; equatorial diameter 16-24 μ ; outline in polar view predominantly four sided. Exine scabrate, thickness about 0.5 μ with no visible evidence of stratification; arc approximately 1 μ wide and deeply convex inward so that any two arc meeting at a pore are usually parallel to each other for a short distance before they reach the pore. Pores typically, though not always four in number; pore outline elliptical with major axis meridionally directed; exine in pore region centrifugally thickened to form a distinct labrum; a vestibulum is not present.

Differential diagnosis.—*Alnus quaternaria*, n. sp. is readily differentiated from *A. trina*, n. sp. by characteristically having four pores and narrow, convex inward arc.

Occurrence.—*Alnus quaternaria*, n. sp. was found to occur sporadically in samples from the Crow Butte section.

Frequency.—"Infrequent."

***Alnus trina* Stanley, n. sp.**

Pl. 43, figs. 4-6

Holotype.—Slide S-1-18 (NS) B; location 31.0×111.1 ; Pl. 43, fig. 4.

Isotype.—Slide S-1-18-8; location 41.7×108.2 ; Pl. 43, fig. 5.

Type locality.—North Cave Hills, Harding Co., South Dakota.

Type horizon.—Ludlow member, Fort Union formation, Paleocene.

Name derivation.—*Trinus*=three; after the three pores which are most typical of this species.

Description.—Mostly triporate oblate pollen grains; equatorial diameter $13-19 \mu$; outline in polar view usually triangular. Exine scabrate; thickness about 0.5μ with no visible stratification present; arci wide with a width of 1.5 to 2.5μ ; arci more or less parallel sides of grain and are not markedly curved. Pores most frequently three in number, occasionally four pores may be present; pore outline elliptical with major axis meridionally directed; exine in pore region centrifugally thickened to form an anulus and a slight labrum; no evidence of a vestibulum is present.

Differential diagnosis.—*Alnus trina*, n. sp. is readily separated from *A. quaternaria*, n. sp. by having characteristically three pores and a much wider arcus that more or less parallels the side of the grain.

Occurrence.—*Alnus trina*, n. sp. was found to occur in the lower part of zone I of the North Cave Hills and also in the Twin Butte sections.

Frequency.—"Infrequent."

Genus **BETULA** (Tourn.) L., 1753

Betula L. (pollen), Wodehouse, 1935, Pollen Grains, p. 366.

Betula L. (pollen), Thiergart, 1940, Schr. Geb. Brennstein-Geol., pt. 13, p. 39.

Betula L. (pollen), Pokrovskaia, 1950, Analyse Pollinique, p. 187.

Trivestibulopollenites Pflug in Thomson and Pflug, 1953, Palaeontographica, vol. 94, pt. B, p. 84.

Betula L. (pollen), Erdtman, 1954, Pollen Analysis, p. 72.

Betula L. (pollen), Leopold, 1956, Grana Palynologica, vol. 1, No. 2, p. 140.

Betula L. (pollen), Golubeva, 1957, Doklady Akad. Nauk S.S.S.R., vol. 114, No. 3, p. 645.

Betulaceipollenites Potonie, 1960, Beih. Geol. Jb., vol. 39, p. 114.

Betula L. (pollen), Kuprianova, 1963, Taxon, vol. 12, No. 1, p. 12.

Description.—Spheroidal to subspheroidal pollen grains; predominantly triporate; diameter 20-40 μ (after Wodehouse, 1935). Endexine about 0.5 μ thick; ectexine smooth, scabrate or weakly granulate and has a thickness of approximately 1 μ . Pores almost always three in number, a distinct labrum and anulus as well as a distinct vestibulum are present.

Discussion.—Erdtman (1954, p. 22) mentioned that arci are present in the pollen of *Betula*. The writer has examined some 13 slides representing pollen of 6 species of *Betula* including *B. glandulosa* which Erdtman stated has "well defined arci." None of the species examined has distinct or clear arci. It is true that certain folds are present in the exine. These folds do not tend to be regularly oriented and are not interpreted as arci.

What is thought to be more characteristic than perhaps indistinct arci is the vestibula. This structure was present in all specimens of the six species examined and in all other specimens of *Betula* pollen that the writer has observed in the past. It is thought to be the most characteristic feature of the pollen of the genus.

Differential diagnosis.—The general construction of the pollen together with the vestibulum readily differentiate pollen of *Betula* from other similar pollen.

***Betula infrequens* Stanley, n. sp.**

Pl. 43, figs. 7-11

Holotype.—Slide G-1-8a-2; location 35.8 $\times$ 108.0; Pl. 43, figs. 7-8.

Type locality.—North Cave Hills, Harding Co., South Dakota.

Type horizon.—Ludlow member, Fort Union formation, Paleocene.

Name derivation.—*Infrequens*=seldom, rare; after the few specimens of this species encountered.

Description.—Suboblate triporate pollen grains; outline in polar view more or less circular; equatorial diameter 20-28 μ . Endexine about 0.5 μ thick; ectexine approximately 1 μ thick; sculpture a faint granulation. Pores more or less round with a diameter of about 1.5 μ and equatorially located; labrum, anulus, and vestibulum present. A foldlike structure roughly parallels the outline

of the pollen grain; this feature is interpreted as a fold due to compaction of an originally spherical grain and not an arcus.

Differential diagnosis.—The presence of a vestibulum readily separates this species from other similar species described in this paper. The above description should serve to separate this new species from the three species described and assigned to *Trivestibulopollenites* by Pflug in Thomson and Pflug (1953).

Occurrence.—*Betula infrequens*, n. sp. was found to occur only in sample 1-8 from the upper part of Zone I of the North Cave Hills section.

Frequency.—"Infrequent."

Genus **CARPINUS** (Tourn). L., 1753

Carpinus L. (pollen), Wodehouse, 1935, Pollen Grains, p. 368.

Carpinus L. (pollen), Pokrovskaja, 1950, Analysis Pollinique, p. 191.

Triporopollenites Pflug and Thomson, (in part) in Thomson and Pflug, 1953. Palaeontographica, vol. 94, pt. B, p. 82.

Carpinus L. (pollen), Erdtman, 1954, Pollen Analysis, p. 76.

Triporopollenites Pflug and Thomson (in part), Potonie, 1960, Beih. Geol. Jb., vol. 39, p. 116.

Description.—Oblate to subspherical triporate to tetraporate (occasionally five pores) pollen grains, outline in polar view subtriangular, triangular (for triporate grains) or quadrate (for tetraporate grains); equatorial diameter 21-41 μ . Endexine about 0.5 μ thick; ectexine thickness 1 μ , ornamentation wanting to scabrate. Pores equatorially located and more or less circular; in the pore region the ectexine and endexine are flexed centrifugally forming a labrum without an anulus.

Differential diagnosis.—The lack of a thickened region in the pore area usually permits the separation of pollen of this genus from other genera (especially in the Betulaceae) that produce similar pollen.

Carpinus subtriangula Stanley, n. sp.

Pl. 43, figs. 12-16

Holotype.—Slide 18-2-1; location 44.6 $\times$ 109.8; Pl. 43, figs. 13-14.

Isotype.—Slide 18-3-1; location 33.7 $\times$ 95.6; Pl. 43, fig. 15.

Type locality.—Southern half of sec. 24, T. 23 N., R. 9 E., Harding Co., South Dakota.

Type horizon.—Cannonball member, Fort Union formation, Paleocene.

Name derivation.—*Triangulus*=triangle; after the subtriangular outline of most members of this species in polar view.

Description.—Oblate triporate to tetraporate pollen grains; outline in polar view subtriangular to subcircular; equatorial diameter 27-33 μ . Endexine less than 0.5 μ thick; ectexine scabrate, thickness a little greater than 0.5 μ . Pore circular in outline with a diameter of about 2-3 μ ; ectexine and endexine are flexed outward in pore region to form a labrum.

Differential diagnosis.—The simple type pore structure, the ornamentation, and the thin exine separate this species from other similar species.

Occurrence.—*Carpinus subtriangula*, n. sp. was found to occur throughout most of Zone I of the North Cave Hills section and also in some samples from the Cannonball section.

Frequency.—"Infrequent" to "common."

Genus **CORYLUS** (Tourn.), L., 1753

Corylus (Tourn.), L. (pollen), Wodehouse, 1935, Pollen Grains, p. 369.

Corylus (Tourn.), L. (pollen), Thiergart, 1940, Schr. Geb. Brennstein-Geol., pt. 13, p. 39.

Corylus (Tourn.), L. (pollen), Pokrovskaja, 1950, Analyse Pollinique, p. 190.

Triporopollenites Pflug and Thomson (in part) in Thomson and Pflug, 1953, Palaeontographica, vol. 94, pt. B, p. 82.

Corylus (Tourn.), L. (pollen), Erdtman, 1954, Pollen Analysis, p. 76.

Triporopollenites Pflug and Thomson (in part), Potonie, 1960, Beih. Geol. Jb., vol. 39, p. 116.

Corylus (Tourn.), L. (pollen), Simpson, 1961, Trans. Roy. Soc. Edinburgh, vol. 64, No. 16, p. 444.

Corylus (Tourn.), L. (pollen), Kuprianova, 1963, Taxon, vol. 12, No. 1, p. 12.

Description.—Oblate triporate (occasionally tetraporate) pollen grains; outline in polar view more or less circular; equatorial diameter 22-30 μ . Endexine about 0.5 μ thick; ectexine 1-1.2 μ thick, ornamentation wanting to scabrate. Pores approximately circular in outline; a more or less distinct labrum is present with no or little thickening of the ectexine in the pore region; the endexine usually does not extend up to the pore and often is separated from the ectexine forming a pseudovestibulum-like structure.

Discussion.—In the pollen of extant species of *Corylus* examined by the writer the structures shown by Kuprianova (1963, p. 12) were not observed. Only pollen of three species, however, were available for examination and it may be that the structures in

the pore region illustrated by Kuprianova are present in other species.

Differential diagnosis.—The presence of a labrum with no or perhaps little thickening of the exine in the pore region together with the separation of the endexine from the ectexine are thought to be characteristic enough to separate *Corylus* pollen from other similar pollen.

***Corylus granilabrata* Stanley, n. sp.**

Pl. 43, figs. 17-28

Holotype.—Slide G 1-8a-2; location 23.2 $\times$ 108.0; Pl. 43, figs. 17-18.

Isotype.—Slide G 1-8a-5; location 38.2 $\times$ 98.2; Pl. 43, figs. 19-20.

Type locality.—North Cave Hills, Harding Co., South Dakota.

Type horizon.—Ludlow member, Fort Union formation, Paleocene.

Name derivation.—*Granum*=grain; after the granular labrum present in members of this species.

Description: Triporate pollen grains; outline in polar view circular to not circular; equatorial diameter 20-28 μ . Endexine about 0.5 μ thick; ectexine thickness in the order of 1 μ ; ornamentation scabrate throughout except in the pore region where the sculpture is a fine to moderate granulation. Pores approximately circular in outline with a diameter of about 2 μ ; a weak to moderately well-developed labrum is present; ectexine in pore region may be slightly thickened; endexine does not extend as far as the pore and often separated from the ectexine near the pore region.

Differential diagnosis.—The granular labrum readily separate this species from other similar species described in this paper. This character also serves to differentiate this species from those described by Thomson and Pflug under *Triporopollenites*.

Occurrence.—*Corylus granilabrata*, n. sp. was found to be more or less restricted to the upper part of Zone I of the North Cave Hills section.

Frequency.—"Infrequent" to "common."

Family BUXACEAE

Genus **PACHYSANDRA** Michx., 1803

Pachysandra (pollen), Erdtman, 1952, Pollen Morphology and Plant Taxonomy, p. 86.

- Multiporopollenites* Pflug (in part) in Thomson and Pflug, 1953, *Palaeontographica*, vol. 94, pt. B, p. 94.
Pachysandra (pollen), Ikuse, 1956, *Pollen Grains of Japan*, p. 99, pls. 23, 48.
Multiporopollenites Pflug (in part), Potonie, 1960, *Beih. Geol. Jb.*, vol. 39, p. 136.
Erdtmanipollis Krutzsch, 1962, *Geologie*, vol. 11, No. 3, p. 281.

Discussion.—Gray and Sohma (1964) in their detailed investigation of the pollen of both *Pachysandra* and *Sarcococca* found that in many cases it is difficult to separate pollen of these two related genera. However, these workers are inclined to assign the Paleocene *Pachysandra*-like pollen from the northwestern portion of the Great Plains of the United States to *Pachysandra* rather than *Sarcococca*. Therefore, the polyporate *Pachysandra*-like pollen described in this work are tentatively assigned to *Pachysandra* rather than *Sarcococca*.

***Pachysandra cretacea* Stanley, n. sp.**

Pl. 44, figs. 1-9

Holotype.—Slide SCB 11-9; location 39.7×97.0 ; Pl. 44, figs. 1-3.

Isotype.—Slide SCB 11-4; location 37.2×105.2 ; Pl. 44, fig. 9.

Type locality.—Crow Butte, Harding Co., South Dakota.

Type horizon.—Hell Creek formation, Maestrichtian.

Name derivation.—*Cretacea* after occurrence of this species in sediments of Cretaceous age.

Description.—Polyporate pollen grains; shape spherical to sub-spherical; diameter $20-40 \mu$. Endexine about 0.5μ thick; ectexine elements consist of platelike structures $1.5 \times 1.5 \times 0.5 \mu$ stacked next to, but not touching one another to form walls of a reticulum; where three of these plates come together, an element with a triangular cross-section is to be found; diameter of lumina $3-6 \mu$. Pores about 30 in number, simple in construction with a diameter of about 1.5μ .

Discussion.—To date, this species together with the California occurrence of this genus mentioned by Gray and Sohma (*op. cit.*, p. 1180) are the oldest records of *Pachysandra*.

Differential diagnosis.—*Pachysandra cretacea*, n. sp. is distinguished from *P. procumbentifformis* Samoilovitch by its somewhat smaller size. This new species, for the present, is separated from *Pachysandra pachysandroides* (Krutzsch) Stanley, n. comb. by its greater size variation.

Occurrence.—*Pachysandra cretacea*, n. sp. was found to occur in samples from Zone I and also from Zone II of the Crow Butte section and in one sample from the North Cave Hills section.

Frequency.—"Infrequent."

Family **CAPRIFOLIACEAE** (Provisional assignment)

Genus **CAPRIFOLIIPITES** Wodehouse, 1933

Caprifoliipites Wodehouse, 1933, Bull. Torrey Bot. Club, vol. 60, p. 518.

Tricolporopollenites Pflug in Thomson and Pflug, 1953 (in part), Palaeontographica, vol. 94, pt. B, p. 98.

Caprifoliipites Wodehouse, Potonie, 1960, Beih. Geol. Jb., vol. 39, p. 97.

Type species.—*Caprifoliipites viridifluminis* Wodehouse, 1933.

Description.—Prolate tricolporate pollen grains. Exine reticulate. Colpi long, pores meridionally elongated.

Differential diagnosis.—The meridionally elongated pores separate this genus from *Rhiopites* Wodehouse which has equatorially elongated pores.

Botanical affinities.—Caprifoliaceae?

Caprifoliipites longus Stanley, n. sp.

Pl. 44, figs. 10-14

Holotype.—Slide G 1-11-1; location 31.3×101.3 ; Pl. 44, fig. 10-12.

Isotype.—Slide 1-11-G; location 25.8×92.1 ; Pl. 44, figs. 13-14.

Type locality.—North Cave Hills, Harding Co., South Dakota.

Type horizon.—Ludlow member, Fort Union formation, Paleocene.

Name derivation.—*Longus*=long; after the long pores that are typical of this species.

Description.—Prolate tricolporate pollen grains; length of polar axis $37-49 \mu$; equatorial axis $26-39 \mu$ long, shape-class-index about 1.4. Endexine approximately $0.3-0.4 \mu$ thick; ectexine appears to be a reticulately perforated tectum supported by baculae; ectexine about 1μ thick; lumina in tectum on the order of 0.5μ wide. Colpi long, straight, and slightly open caverna present; apocolpium moderate. Pores meridionally elongated with a length of $8-10 \mu$.

Differential diagnosis.—*Caprifoliipites longus*, n. sp. is separated from *R. crassus*, n. sp. by its thin reticulate exine and from

R. pisinnus, n. sp. by its larger size. It is distinguished from *P. edmondi* Potonie by its long pores.

Occurrence.—This new species was found to occur in the upper part of Zone I of the North Cave Hills section.

Frequency.—"Infrequent."

Family ERICACEAE

Genus ERICACEOIPOLLENITES Potonie, 1960

Ericaceoipollenites Potonie, 1951, Palaeontographica, vol. 91, pt. B, p. 147.

Ericaceoipollenites Potonie, 1951, Mikroskopie, vol. 6, p. 281.

Ericaceoipollenites Potonie, 1960, Beih. Geol. Jb., vol. 39, p. 138.

Type species.—*Ericaceoipollenites roboreus* (Potonie), Potonie, 1960.

Description.—Inaperturate to weakly tricolpate pollen grains that are arranged into a tetrahedral tetrad; shape of individual grains more or less spherical. Exine thin to moderately thick; sculpture wanting to markedly developed. Furrows (after Potonie, 1960, p. 138) "relatively small, in part indistinct."

Discussion.—Examination of pollen of Recent Ericaceae in the author's pollen collection show that all species examined (11 in total), with the exception of one, have distinct furrows. The one exception is *Kalmia latifolia*. It is remarkable that the only plant megafossil that Brown described and placed in the Ericaceae is a species of *Kalmia*. Furthermore, Brown (1962, p. 85) stated that "these leaves compare fairly well with these of mountain-laurel, *Kalmia latifolia* Linneaus of the Eastern United States." There are, however, some morphological differences between the pollen of *Kalmia latifolia* and the fossil pollen under discussion here. Consequently, it at present is assigned to an artificial genus.

Differential diagnosis.—*Ericaceoipollenites* Potonie is separated from *Ericipites* Wodehouse by the absence of well-defined colpi.

Botanical affinities.—Ericaceae.

***Ericaceoipollenites rallus* Stanley, n. sp.**

Pl. 44, figs. 15-18

Holotype.—Slide 18-4-1; location 39.0×108.4 ; Pl. 44, figs. 15-16.

Isotype.—Slide 18-4-2; location 34.1×92.0 ; Pl. 44, figs. 17-18.

Type locality.—Southern half of sec. 24, T. 23 N., R. 9 E., Harding Co., South Dakota.

Type horizon.—Cannonball member, Fort Union formation, Paleocene.

Name derivation.—*Rallus*=thin; after the thin-walled exine which is typical of this species.

Description.—Inaperturate to weakly tricolpate pollen grains that are arranged into a tetrahedral tetrad; shape of individual grains more or less spherical; size of tetrad 25-40 μ ; diameter of individual grains 13-25 μ . Colpi, when observable, short, closed; often the colpus area, in grains that do not yet have distinct colpi, appears granular. Endexine about 0.3 μ thick, ectexine approximately 0.5 μ thick, scabrate.

Discussion.—The exine of this species appears to corrode easily. Most of the specimens examined have partially pitted exines, and this may be due to the thin exine of the species.

Differential diagnosis.—Superficially, *Ericaceoipollenites rallus*, n. sp. resembles *E. roboreus* (Potonie), Potonie. The latter species is considerably larger in size and has a thicker exine.

Occurrence.—*Ericaceoipollenites rallus*, n. sp. was observed to be present in both zones of the North Cave Hills section, in samples from the Twin Butte section and in several samples from the Cannonball section.

Frequency.—"Infrequent" to "common."

Botanical affinities.—*Kalmia*?

Family HALORAGACEAE

Genus **MYRIOPHYLLUM** Ponted. ex L., 1753

Myriophyllum Ponted. ex L., (pollen), Pokrovskaja, 1950, Analyse pollinique, p. 293.

Myriophyllum Ponted. ex L., (pollen), Erdtman, 1951, Pollen Analysis, p. 101.

Discussion.—The writer has not examined pollen of any extant species of *Myriophyllum*. Therefore, no attempt is made to give a description of the pollen produced by members of this genus. Also, there is not too much information available in the literature on the pollen morphology of *Myriophyllum*. The reader is referred to the two works cited above for a discussion and description of the pollen of this genus.

Myriophyllum cf. M. ambiguipites Wodehouse

Pl. 45, figs. 1-2

Myriophyllum ambiguipites Wodehouse, 1933, Bull. Torrey Bot. Club, vol. 60, p. 516, fig. 51.

Myriophyllum ambiguipites Wodehouse, Kremp, Ames and Grebe, 1957. Catalog of Fossil Spores and Pollen, vol. 1, p. 90.

Holotype.—3-11.9-41.0; Wodehouse, 1933.

Description.—Oblate tetraporate pollen grains; outline in polar view subcircular; equatorial diameter about 28 μ . Exine does not appear to be differentiated; exine thickness about 1 μ , texture scabrate. Pores meridionally elongated with an anulus; pore dimensions 4.5 $\mu \times$ 1.2 μ .

Discussion.—The specimens encountered are somewhat larger than the specimen described and illustrated by Wodehouse, 1933. It is felt that the size of these specimens fall well within the size range expected for the species.

Differential diagnosis.—To this writer's knowledge, there are no other species of fossil pollen presently assigned to *Myriophyllum*.

Occurrence.—This species was found to occur only in samples from the Cannonball and Twin Butte sections.

Frequency.—"Infrequent."

Family JUGLANDACEAE**Genus CARYA** Nutt., 1818

Carya Nutt. (pollen), Wodehouse, 1935, Pollen Grains, p. 358.

Caryapollenites Raatz, 1937, Abb. Preuss. geol. L.-A.N.F., pt. 183, p. 17.

Carya Nutt. (pollen), Pokhovskaia, 1950, Analyse Pollinique, p. 180.

Subtriporopollenites Pflug, 1952, Palaeont. Z., vol. 26, pts. 1/2, p. 117.

Subtriporopollenites Pflug and Thomson in Thomson and Pflug, 1953, Palaeontographica, vol. 94, pt. B, p. 85.

Carya Nutt. (pollen), Erdtman, 1954, Pollen Analysis, p. 104.

Carya Nutt. (pollen), Macko, 1957, Lower Miocene Pollen Flora, p. 58.

Caryapollenites Raatz, Potonie, 1960, Beih. Geol. Jb., vol. 39, p. 123.

Description.—Subtriporate to tetraporate pollen grains; outline in polar view circular; diameter in the eight species examined by the author range between 48 and 80 μ . Endexine 0.5 μ thick; ectexine about 2.5 μ thick with the ectexine and endexine often separating from each other. Pores more or less circular, large, structure simple; pores situated off the equator and all positioned in one hemisphere.

Differential diagnosis.—The circular shape and the location of

the pores in one hemisphere readily separate *Carya* pollen from most other types of pollen grains.

***Carya paleocenica* Stanley, n. sp.**

Pl. 45, figs. 3-7

Holotype.—Slide 18-2-1; location 23.5×98.1 ; Pl. 45, figs. 6-7.

Isotype.—Slide 18-2-2; location 34.6×104.1 ; Pl. 45, fig. 3.

Type locality.—Southern half of sec. 24, T. 23 N., R. 9 E., Harding Co., South Dakota.

Type horizon.—Cannonball member, Fort Union formation, Paleocene.

Name derivation.—Named after its apparent restriction to the Paleocene sediments in the South Dakota area.

Description.—Subtriporate to tetraporate pollen grains; outline in polar view more or less circular; equatorial diameter $22-30 \mu$. Exine 1.5μ thick, appears to be one-layered; sculpture scabrate to weakly granulate. Pores subequatorial, large, circular; diameter 3μ .

Differential diagnosis.—*Carya paleocenica*, n. sp. differs from *C. veripites* Wilson and Webster in generally being smaller in size. There is a small overlap in the extremes of the two species. *Carya veripites* Wilson and Webster also has a smooth exine whereas the exine of *C. paleocenica*, n. sp. is scabrate to weakly granulate. *Carya simplex* (Potonie) n. comb. has a much thicker exine than the new species described above. All the species of *Carya* (*Subtriporopollenites*) described by Thomson and Pflug, 1953 have a different exine sculpture or a different size range than *C. paleocenica*, n. sp.

Occurrence.—*Carya paleocenica*, n. sp. was found to occur only in samples 18-2 and 18-3 from the Cannonball section.

Frequency.—"Infrequent."

Genus **ENGELHARDTIA** Leschen, 1825

Momipites Wodehouse, 1933 (in part), Bull. Torrey Bot. Club. vol. 60, p. 511.

Engelhardtia Leschen, (pollen), Wodehouse, 1935, Pollen Grains, P. 361.

Engelhardtia Leschen, (pollen), Pokrovskaja, 1950, Analyse Pollinique, p. 180.

Engelhardtia Leschen, (pollen), Erdtman, 1954, Pollen Analysis, p. 106.

Momipites Wodehouse, Potonie, 1960, Beih. Geol. Jb., vol. 39, p. 118.

Engelhardtia Leschen, (pollen), Simpson, 1961, Roy. Soc. Edinburgh, Trans., vol. 64, No. 16, p. 445.

Description.—Oblate triporate pollen grains; outline in polar view triangular with pores located at apexes; diameter 9μ (some specimens of *E. chrysolepis*) to about 15μ . Exine thickness about

0.9 μ with endexine and ectexine being approximately equal in thickness; ectexine scabrate. Endexine on many specimens terminates some distance from the pore region forming an atriumlike structure; this is often reflected in a lighter area around the pore. Pores small, meridionally elongated.

Discussion.—Although Brown, 1962, did not report *Engelhardtia* present among the plant megafossils he wrote (*op. cit.* p. 56):

So far as I am aware there is no reliable method for distinguishing between the many fossil leaflets assigned to *Carya* and *Juglans*. Consequently, those here called *Carya* may represent several species of *Carya*, or a mixture of *Carya*, *Juglans* and other juglandaceous genera such as *Engelhardtia*, *Platycarya*, and *Rhoipetelea*.

Palynologically, all of the above juglandaceous genera can be separated and this lends support to this writer's philosophy that the classical paleobotanists and the palynologists have to work together if some of the problems of the evolution and distribution of plants through geologic time are to be resolved.

Differential diagnosis.—The pollen of *Engelhardtia* are more or less distinctive so that there is little chance for confusion with the pollen of *Platycarya*, *Corylus*, or *Celtis* (*Momisia*). The writer has not seen the pollen of *Momisia iguanacea* with which Wodehouse compared his fossil pollen. However, pollen of six species of *Celtis* have been examined and none compares very closely with the fossil pollen species assigned to *Engelhardtia*. Pollen of one extant species of *Engelhardtia* have been examined (*E. chrysolepsis*) and there is thought to be a close relationship between it and the fossil pollen species described herein. Recently, Dr. Estella B. Leopold informed the writer (personal communication) that the pollen of *Alfaroa* is morphologically close to that of *Engelhardtia*. Inasmuch as the pollen of *Alfaroa* has not been seen by the writer the pollen resembling *Engelhardtia* described in this study is tentatively assigned to this latter genus.

***Engelhardtia microfoveolata* Stanley, n. sp.**

Pl. 45, figs. 8-13

Holotype.—Slide 18-2-1; 29.7 $\times$ 107.5; Pl. 45, figs. 8-10.

Isotype.—Slide 18-3-1; 23.9 $\times$ 127.8; Pl. 45, fig. 13.

Type locality.—Southern half of sec. 24, T. 23 N., R. 9 E. Harding Co., South Dakota.

Type horizon.—Cannonball member, Fort Union formation, Paleocene.

Name derivation.—Named after the small pits or depressions in the exine.

Description.—Oblate triporate pollen grains, outline in polar view triangular with straight to slightly convex sides and rounded apices; equatorial diameter 15-22 μ . Endexine about 0.3 μ thick; ectexine thickness on the order of 0.6 μ making a total exine thickness of about 1 μ . Sculpture a fine punctation with lumina approximately 0.3 μ wide. Pores meridionally elongated; dimensions $1 \times 1.5 \mu$. Some specimens have arclike area that surrounds the pore region (see Pl. 45, fig. 11); this feature does not appear to be caused by the thickening of the exine but rather appears to be the result of more stain being accepted in this arclike region due perhaps to differences in exine chemistry.

Differential diagnosis.—Although the writer has not examined the type of *Engelhardtia (Momipites) coryloides* (Wodehouse), n. comb., he has examined several slides of samples from the Green River oil shales of Utah. These shales contained an abundant number of specimens of *Engelhardtia coryloides* (Wodehouse), n. comb. and it is on the basis of this examination that this differential diagnosis is made. In general, *E. coryloides* (Wodehouse) is a larger species although there is some overlap between it and *E. microfoveolata*, n. sp. The exine of *E. coryloides* (Wodehouse) is thick (generally two or more micra) and the pores are larger (about 2 μ wide and 2.5-3 μ long). The exine of Wodehouse's species is also finely pitted as in the new species described here. This fact is not mentioned by Wodehouse, but it should be kept in mind that microscope optics have greatly improved since the early 1930's.

The new species described above neither has the thin polar areas as *Engelhardtia tenuipolis* (Anderson), n. comb. nor the smooth exine of *E. triletipollenites* Rouse.

Occurrence.—*Engelhardtia microfoveolata*, n. sp. was found to occur in samples from Zone I of the North Cave Hills section and in samples from the Cannonball and Twin Butte sections.

Frequency.—"Infrequent."

Genus **PTEROCARYA** Kunth., 1824

- Pterocarya* Kunth., (pollen), Wodehouse, 1935, Pollen Grains, p. 362.
Pterocaryapollenites Thiergart, 1938, Jb. preuss. geol. L-A., vol. 58, p. 311.
Pterocarya Kunth., (pollen), Pokrovskaja, 1950, Analyse Pollinique, p. 179.
Polyatriopollenites Pflug, 1953 (in part), Palaeontographica, vol. 95, pt. B, p. 115.
Pterocarya Kunth., (pollen), Erdtman, 1954, Pollen Analysis, p. 106.
Pterocarya Kunth., (pollen), Macko, 1959, Pollen Grains and Spores from Miocene from Coals in lower Silesia, pp. 14, 18.
Pterocaryapollenites Thiergart ex Potonie, 1960, Beih. Geol. Jb., vol. 39, p. 132.
Pterocarya Kunth., (pollen), Samoilovitch, *et al.*, 1961, Pollen and Spores from Western Siberia, p. 156.

Description.—Oblate polyporate pollen grains; outline in polar view polygonal to subcircular depending on pore number; equatorial diameter $27-34\ \mu$ (after Wodehouse). Endexine about $0.5\ \mu$ thick; ectexine thickness approximately $1\ \mu$. Sculpture (in *P. hupehensis*) finely granulate with grana about $0.5\ \mu$ in diameter. Pores slightly to moderately elongated meridionally, size $3 \times 1.5\ \mu$. Endexine terminates about $3\ \mu$ from pore edge forming an atrium-like structure which results in a light halo-like area around the pore.

Discussion.—Fossil pollen assigned to *Pterocarya* has been found in both the Upper Cretaceous and Paleocene sediments investigated for this report. Brown (1962) reported fossil leaves and nutlets from the Fort Union formation which he placed in this genus. Dorf (1942) did not report any plant megafossils assignable to *Pterocarya* from the Upper Cretaceous Lance Formation of Wyoming.

Differential diagnosis.—Pollen of *Pterocarya* is thought to be morphologically different enough from other similar pollen that it is believed that there is little chance for confusion. However, there well may be some other genera that this writer doesn't know about that does have pollen similar to *Pterocarya*. This, however, is always a risk in this type of investigation.

Pterocarya grandis Stanley, n. sp.

Pl. 45, figs. 14-17

Holotype.—Slide G 1-8-4; location 43.8×98.7 ; Pl. 45, fig. 14.

Isotype.—Slide G 1-8a-4; location 28.7×97.6 ; Pl. 45, fig. 15.

Type locality.—North Cave Hills, Harding Co., South Dakota.

Type horizon.—Ludlow member, Fort Union formation, Paleocene.

Name derivation.—*Grandis*=large; after the large size of this species as compared to *Pterocarya laeva*, n. sp.

Description.—Oblate polyporate pollen grains; outline in polar view pentameral (only five-pored grains have been observed); equatorial diameter 25-32 μ . Endexine approximately 0.3-0.5 μ thick; ectexine thickness 1.2-1.5 μ ; texture scabrate to psilate. Pores five in number, meridionally elongated; endexine terminates near pore forming a small atrium-like structure; pore size approximately $2 \times 4 \mu$.

Differential diagnosis.—*Pterocarya grandis*, n. sp. is readily separated from *P. levis* by its thicker exine and larger equatorial diameter. Of the seven new species of *Pterocarya* described by Wojcel (p. 156, in Samoilovitch, *et al.*, 1961) only one species, *Pterocarya stenopteroides* Wojcel, characteristically has five pores. The exine in this latter species is finely granulated rather than psilate to scabrate. *Pollenites stellatus* Potonie differs from this new species in usually having six pores and appears to have a thinner exine.

Occurrence.—*Pterocarya grandis*, n. sp. was found to only occur in a sample from the upper part of Zone I of the North Cave Hills section.

Frequency.—"Infrequent."

***Pterocarya levis* Stanley, n. sp.**

Pl. 45, figs. 18-23

Holotype.—Slide SCB-11-9; location 26.1 $\times$ 105.3; Pl. 45, fig. 18.

Isotype.—Slide SCB-12-4; location 39.5 $\times$ 95.7; Pl. 45, fig. 22.

Type locality.—Crow Butte, Harding Co., South Dakota.

Type horizon.—Hell Creek formation, Maestrichtian.

Name derivation.—*Levis*=smooth; after the smooth or sculptureless exine of this species.

Description.—Oblate polyporate pollen grains; outline in polar view a reflection of pore number, sides straight to concave outward; equatorial diameter 15-19 μ . Exine 1 to 1.5 μ thick, distinctly two-layered; endexine about 0.6 μ thick; ectexine 1 μ thick, smooth. Pores five-six in number; endexine terminates about 1.5 μ from

pore opening forming an atrium-like structure; pores meridionally elongated with a width of about $1\ \mu$.

Differential diagnosis.—*Pterocarya levis*, n. sp. differs from *Pollenites stellatus* Potonie and *Pterocarya vermontensis* Traverse by its considerably smaller size. It resembles *Pollenites verus* Potonie (1932) but upon examination of the redescription and reillustration of the species in Potonie 1934 (p. 58; pl. 2, figs. 13, 17, 18, 25, and 26; p. 6, fig. 28) it appears that this species is assignable to *Alnus* rather than *Pterocarya*.

Occurrence.—*Pterocarya levis*, n. sp. was found to occur in Zone II of the Crow Butte section.

Frequency.—"Infrequent."

Family **OLACACEAE** (Provisional assignment)

Genus **ANACOLOSIDITES** Cookson and Pike emended Potonie, 1960

Anacolosidites Cookson and Pike, 1954, Australian Jour. Bot., vol. 2, No. 2, p. 207.

Anacolosidites Cookson and Pike, Krutzsch, 1959, Geol., vol. 8, No. 21-23, p. 243.

Anacolosidites Cookson and Pike emended Potonie, 1960, Beih. Geol. Jb., vol. 39, p. 124.

Type species.—*Anacolosidites luteoides* Cookson and Pike, 1954.

Description.—Oblate hexaporate pollen grains; outline in polar view circular to triangular with sides convex to slightly concave. Exine sculpture variable; thickness variable. Pores subequatorial with three located in each hemisphere.

Discussion.—The genus *Anacolosidites* was originally defined by Cookson and Pike to include hexaporate pollen grains with triangular to subtriangular outline in polar view. Later, Potonie emended the generic description to include similar pollen grains with a circular outline in polar view.

Differential diagnosis.—*Anacolosidites* is characterized by the presence of six pores, three lying in each hemisphere. *Caryapollenites* is somewhat similar but it has only three pores restricted to one hemisphere, the other hemisphere being devoid of pores.

Botanical affinities.—Cookson and Pike believed *Anacolosidites* to be related to the extant genus *Anacolosa*. Krutzsch, 1959, mentioned that the genera *Cathedra* and *Ptychopetalum*, also in the Olacaceae, have similar pollen.

Anacolosidites rotundus Stanley, n. sp.

Pl. 45, figs. 24-28

Holotype.—Slide S 8-1a-8; location 25.3×108.5 ; Pl. 45, figs. 24-25.

Isotype.—Slide S 8-1a-2; location 30.8×105.4 ; Pl. 45, figs. 26-28.

Type locality.—Crow Butte, Harding Co., South Dakota.

Type horizon.—Hell Creek formation, Maestrichtian.

Name derivation.—*Rotundus*=circle; after the circular shape of this species in polar view.

Description.—Oblate hexaporate pollen grains; outline in polar view circular; equatorial diameter $18-34 \mu$. Endexine about 0.5μ thick, ectexine elements consisting of muri forming a mesh pattern; muri height $1-1.2 \mu$; lumina approximately 0.5μ wide at polar areas and widening to 1μ at the equatorial region. Pores more or less circular, subequatorial, six in number with three located in each hemisphere; pores surrounded by a thin anulus; pore diameter $5-6 \mu$.

Differential diagnosis.—*Anacolosidites rotundus*, n. sp. is distinguished from most other species presently assigned to the genus by its circular outline in polar view. *Anacolosidites insignis* Samoilovitch (in Mtchedlishvili and Samoilovitch, 1960 and also in Samoilovitch, *et al.*, 1962) has a circular outline in polar view. However, this species appears to have a mesh sculpture that has elongated lumina near the periphery, a feature lacking in the new species described here.

Occurrence.—This new species was found to occur in samples from Zones I and II of the Crow Butte section.

Botanical affinities.—See discussion under the generic description.

Frequency.—"Infrequent."

Family **OLEACEAE** (Provisional assignment)

Genus **FRAXINOIPOLLENITES** Potonie, 1960

Fraxinoipollenites Potonie, 1951, *Sond. aus Mikroskopie*, vol. 6, nos. 3/10, fig. 49.

Fraxinoipollenites Potonie, 1951, *Palaeontographica*, vol. 41, pt. B, pl. 21, figs. 174-175.

Tricolpopollenites Pflug and Thomson (in part) in Thomson and Pflug, 1953, *Palaeontographica*, vol. 94, pt. B, p. 95.

Fraxinoipollenites Potonie, 1960, *Beih. Geol. Jb.*, vol. 39, p. 84.

Type species.—*Fraxinoipollenites pudicus* (Potonie), Potonie.

Description.—Prolate tricolpate pollen grains. Exine scabrate to reticulate. Colpi long, distinct.

Discussion.—The two works by Potonie (1951 a, b, cited above) do not validate this generic name. The first valid name for this genus is *Tricolpopollenites* Pflug and Thomson, and this genus is considered to be further subdivided by Potonie so that the present valid name is thought to be *Fraxinoipollenites* Potonie, 1960.

Differential diagnosis.—The sculpture is considered to be significant in separating this genus from *Tricolpopollenites* and other similar tricolpate genera.

Botanical affinities.—In part *Fraxinus*?

Fraxinoipollenites variabilis Stanley, n. sp. Pl. 45, figs. 29-35

Holotype.—Slide 18-2-12; location 33.6×104.2 ; Pl. 45, figs. 29-30.

Isotype.—Slide 18-2-3; location 34.1×109.2 ; Pl. 45, figs. 31-32.

Type locality.—Southern half of sec. 24, T. 23 N., R. 9 E., Harding County, South Dakota.

Type horizon.—Cannonball member, Fort Union formation, Paleocene.

Name derivation.—*Variabilis*=changeable; after the moderate variation in the shape-class-index of this species.

Description.—Prolate tricolpate pollen grains; length of polar axis $18-25 \mu$; equatorial diameter $15-23 \mu$; shape-class-index 1.1 to 1.5. Endexine about 0.5μ thick, ectexine sculpture elements clavate forming a reticulum with lumina 0.5μ wide; length of clavate 1μ . Colpi long, straight to slightly sinuous and closed; apocolpium very small.

Differential diagnosis.—This species is distinguished from *F. pudicus* (Potonie), Potonie by its considerably smaller size. It is separated from *Tricolpopollenites retiformis* Pflug and Thomson by its clavate rather than baculate sculpture.

Occurrence.—This species was found to occur in samples from the upper part of Zone I and also in samples from the Cannonball section.

Botanical affinities.—*Fraxinus*?

Frequency.—"Infrequent."

Family **PROTEACEAE** (Provisional assignment)Genus **PROTEACIDITES** Cookson, 1950

Proteacidites Cookson, 1950, Australian Jour. Sci., Ser. B, vol. 3, No. 2, p. 170.

Proteacidites Cookson, Couper, 1953, New Zealand Geol. Sur. Paleont. Bull. 22, p. 42.

Proteacidites Cookson, Potonie, 1960, Beih. Geol. Jb., vol. 39, p. 122.

Proteacidites Cookson, Samoilovitch, *et al.*, 1961, Pollen and Spores from Western Siberia, p. 168.

Type *species*.—*Proteacidites adenantoides* Cookson, 1950. (subsequent designation by Couper, 1913, p. 42).

Description.—Oblate triporate pollen grains; outline in polar view more or less triangular with pores apically located. Exine distinctly trilayered; sculpture reticulate, baculate, clavate or tuberculate. Pores large, an endanulus may or may not be present.

Differential diagnosis.—The outline, together with the distinctly layered exine, separates this genus from other similar genera as for example *Conclavipollis* Pflug.

Botanical affinities.—*Proteaceae*?

Proteacidites retusus Anderson, 1960

Pl. 46, figs. 1-6

Triporate pollen, Sarmiento, 1957, Amer. Assoc. Petrol. Geol., Bull. vol. 41, No. 8, figs. 3, 4.

Proteacidites retusus Anderson, 1960, New Mexico Bureau Mines and Min. Res., Mem. 6, p. 21, pl. 2, figs. 5-7.

Holotype.—Anderson, 1960, collection number AK 11-1.

Description.—Oblate triporate pollen grains; outline in polar view triangular with slightly convex to concave sides; equatorial diameter 20-25 μ . Endexine about 0.5 μ thick, except in pore area where it thickens to about 1.5 μ to form the "apertural collar" of Cookson, 1950. Ektexine reticulately sculptured with lumina about 0.5 μ wide at the polar regions and widening to 1-1.5 μ at the equatorial area; muri 0.5 to 1 μ high. Pores apically located, more or less large (5-6 μ); endanulus (apertural collar) present.

Differential diagnosis.—*Proteacidites retusus* Anderson resembles *P. restomarginis* Cookson and *P. callosus* Cookson but is much smaller in size than these species.

Occurrence.—*Proteacidites retusus* Anderson was found to occur in Zone III and the lower part of Zones I and II of the Crow Butte section.

Botanical affinities.—Proteaceae?

Frequency: "Infrequent."

Family **ROSACEAE** (Provisional assignment)

Genus **QUERCROIDITES** Potonie emended (in this work)

Quercoidites Potonie, Thomson and Thiergart, 1950, Geol. Jb., vol. 61, p. 54.

Quercoidipollenites Potonie, 1951, Palaeontographica, vol. 91, pt. B, pl. 20, fig. 6+.

Tricolpopollenites Pflug and Thomson (in part) in Thomson and Pflug, 1953, Palaeontographica, vol. 94, pt. B, p. 95.

Quercoidites Potonie, Thomson and Thiergart ex Potonie, 1960, Beih. Geol. Jb., vol. 39, p. 92.

Description.—Prolate tricolpate pollen grains with a distinct geniculus. Exine sculpture baculate to muronate.

Discussion.—This artificial genus is here emended to include muronate fossil pollen grains as well as baculate ones. The name *Quercoidites* Potonie, Thomson and Thiergart and *Quercoidipollenites* Potonie are here considered *nomina nuda* inasmuch as the mere mentioning of a name together with a previously described species cannot be considered as validation of the name. The name *Quercoidites* is not thought to be legitimate until 1960 with the publication of part 3 of Potonie's synopsis.

Differential diagnosis.—The sculpture and the presence of a distinct geniculus separate this genus from other similar genera.

Botanical affinities.—This artificial genus probably contains a conglomeration of many different natural plant genera. Affinities for this group have to be discussed at the species level.

Quercoidites genustriatus Stanley, n. sp.

Pl. 46, figs. 7-11

Holotype.—Slide SCB 11-7; location 29.6×111.2 ; Pl. 46, figs. 7-9.

Isotype.—Slide SCB 11-11; location 28.5×106.5 ; Pl. 46, figs. 10-11.

Type locality.—Crow Butte, Harding Co., South Dakota.

Type horizon.—Hell Creek formation, Maestrichtian.

Name derivation.—After the presence of a geniculus and a striate exine sculpture.

Description.—Prolate tricolpate (or possibly tricolporate) nollen; length of polar axis $27-34 \mu$; equatorial axis $22-25 \mu$ long; shape-class-index about 1.8. Endexine approximately 0.5μ thick; ectexine

sculpture elements consist of muri that are caniculate arranged into a striate pattern; muri $1.5\ \mu$ high and $1\ \mu$ wide; vallae about $0.3\text{--}0.5\ \mu$ wide. Colpi long, straight, and slightly open; in the center of each colpus is a prominent geniculus with perhaps an indistinct pore.

Differential diagnosis.—The combination of the striate sculpture and the geniculi separate this species from other similar species.

Occurrence.—*Quercoidites genustriatus*, n. sp. was found to occur in Zones I and II of the Crow Butte section.

Botanical affinities.—The importance of the geniculus was discussed in a paper by Stanley and Kremp (1959). Unfortunately, in the list of families that have pollen with a geniculus (*op. cit.* p. 354) the Rosaceae was omitted through an oversight. It is presently thought that the new species described above probably has affinities with the Rosaceae (see *Comarum palustre* in Erdtman, 1943, p. 119).

Frequency.—"Infrequent."

Family **SAPINDACEAE** (Provisional assignment)

Genus **CUPANIEIDITES** Cookson and Pike, 1954

Cupanieidites Cookson and Pike, 1954, Australian Jour. Bot., vol. 2, No. 2, p. 210.

Cupanieidites Cookson and Pike, Krutzsch, 1959, Palaeontographica, vol. 105, pt. B, p. 144.

Cupanieidites Cookson and Pike, Potonie, 1960, Beih. Geol. Jb., vol. 39, p. 106.

Type species.—*Cupanieidites orthoteichus* Cookson and Pike, 1954.

Description.—Oblate syntricolporate pollen grains; outline in polar view triangular with side weakly to moderately convex or concave; size variable. Exine ornamentation punctate to weakly reticulate.

Differential diagnosis.—The absence of distinct polar areas (apocolpium) distinguishes this species from *Myrtaceidites* Cookson and Pike, 1954, and *Duplopollis* Krutzsch, 1959.

Botanical affinities.—See the discussion under the species description.

Cupanieidites speciosus Stanley, n. sp.

Pl. 46, figs. 12-17

Holotype.—Slide S 8-1a-3; location 45.7×101.8 ; Pl. 46, figs. 12-13.

Isotype.—Slide S 8-1a-1; location 39.0×112.2 ; Pl. 46, figs. 14-15.

Type locality.—Crow Butte, Harding Co., South Dakota.

Type horizon.—Hell Creek formation, Maestrichtian.

Name derivation.—*Speciosus*=beautiful, splendid; after the appearance of this species.

Description.—Oblate tricolporate pollen grains; outline in polar view triangular with rounded apices; equatorial diameter 18-25 μ . Endexine 0.5 μ thick; ectexine about 1 μ thick between apices and thickens to 1.5-2.5 μ at apices; sculpture a pitting or fine reticulation with lumina on the order of 0.3 μ wide. Colpi long, straight, closed and meet at the polar areas. Pores are apically located and indistinct.

Differential diagnosis.—*Cupanieidites speciosus*, n. sp. differs from *C. orthoteichus* Cookson and Pike by lacking the "polar islands" mentioned by these authors.

Occurrence.—This species was found to occur in samples from Zone I and the upper part of Zone II of the Crow Butte section.

Botanical affinities.—Possibly *Cupanieae*; see Cookson and Pike, 1954, plate 2, for pollen of some extant species.

Frequency.—"Infrequent."

Family VITACEAE

Genus VITIS (Tourin.), L., 1753

Vitipites Wodehouse, 1933, Bull. Torrey Bot. Club, vol. 60, p. 514.

Vitipites Wodehouse emended Potonie, 1960, Beih. Geol. Jb., vol. 39, p. 105.

Nyssapollenites Thiergart ex Potonie, 1960 (in part), Beih. Geol. Jb., vol. 39, p. 103.

Description.—Spherical to oblate tricolporate pollen grains; outline in polar view subtriangular to subround; equatorial diameter 18-37 μ . Exine about 1 μ thick; sculpture scabrate to finely reticulate. Colpi long, straight, and open; apocolpium small. Pores round and usually indistinct.

Discussion.—For a long time the pollen grains, herein placed in *Vitis*, were thought by the author to be assignable to *Nyssa*. This writer was never completely satisfied with the assignment inasmuch as there were too many discrepancies involved. For instance, *Nyssa* pollen, to the writer's knowledge is always fairly large; it has a distinct pore that is surrounded by an annulus and has weakly granulate

sculpturing. The fossil pollen herein assigned to *Vitis* are always small, always have an indistinct pore, and have a weakly reticulate sculpture. It is true that the pollen of *Vitis* can be fairly large. The range, on the lower end, extends close to the upper limit of the fossil pollen under discussion. Although plant megafossils of both *Nyssa* and *Vitis* have been recovered from the Paleocene sediments in the area, it appears to this writer that an assignment of the species described below to *Vitis* is more reasonable than an assignment to *Nyssa*.

Differential diagnosis.—A reticulately sculptured exine together with indistinct pores are thought to be the characters that one often can use to separate pollen of *Vitis* from those of *Nyssa*.

***Vitis* ? *affluens* Stanley, n. sp.**

Pl. 46, figs. 18-21

Holotype.—Slide S-1-18-9; location 28.8×108.7 ; Pl. 46, fig. 19.

Isotype.—Slide S-1-18-8; location 27.0×93.6 ; Pl. 46, fig. 21.

Type locality.—North Cave Hills, Harding Co., South Dakota.

Type horizon.—Ludlow member, Fort Union formation, Paleocene.

Name derivation.—*Affluens*=abundant, rich; after the abundant number of specimens found in some samples.

Description.—Oblate tricolporate pollen grains; outline in polar view subtriangular; equatorial diameter $15-21 \mu$. Exine distinctly two layered; endexine about 0.1μ thick; ectexine approximately 0.5μ thick between colpi and thins toward colpus edge; sculpture faintly reticulate with lumina on the order of 0.3μ wide. Colpi long, straight, and open; apocolpium small. Pores simple, circular with a diameter of about 2μ .

Differential diagnosis.—This species somewhat resembles *Polenites kruschi* Potonie. It can be differentiated from it by its smaller size and its finely reticulate exine.

Occurrence.—*Vitis* ? *affluens*, n. sp. was found to be restricted to the upper part of Zone II and the lower part of Zone I of the North Cave Hills section.

Frequency.—"Infrequent" to "common" in some samples.

INCERTAE FAMILIAE-POLLEN

Genus **AENIGMAPOLLIS** Stanley, n. gen.

Type species.—*Aenigmapollis polyformis* Stanley, n. sp.

Name derivation.—*Aenigma*=something obscure; after the obscure colpus or pore of the type species.

Description.—See specific description.

Differential diagnosis.—See discussion under the species.

Aenigmapollis polyformis Stanley, n. sp.

Pl. 46, figs. 22-25

Holotype.—Slide G 1-7-1; location 24.9×94.3 ; Pl. 46, figs. 22-23.

Isotype.—Slide G 1-7-2; location 34.8×98.5 ; Pl. 46, figs. 24-25.

Type locality.—North Cave Hills, Harding Co., South Dakota.

Type horizon.—Ludlow member, Fort Union formation, Paleocene.

Name derivation.—*Polyforma*; after the variety of forms and positions this species can be found.

Description.—Oblate subcircular to spheroidal tricolporate pollen grains; diameter $16-21 \mu$. Endexine approximately 0.3μ thick with the exception of the pore area where it thickens to about 1μ ; ectexine 0.5μ thick, texture scabrate. Colpi short, slitlike to slightly opened, often indistinct. Pores meridionally elongated, also often indistinct (especially when grain is viewed from a polar position), pore surrounded by an annulus that is widest in the meridional portion.

Differential diagnosis.—*Aenigmapollis polyformis*, n. sp. resembles *Triporpollenites plektosus* Anderson. In the latter species, the pores appear to be circular and there is no mention of colpi being present. The new species here described also resembles *Triporina globosa* Chlonova. However, it does not have the complicated pore structure as shown by Chlonova (in Samoilovitch, *et al.* pl. 80, figs. 2c, 3b).

Occurrence.—*Aenigmapollis polyformis*, n. sp. was found to occur most abundantly in the upper most part of Zone I of the North Cave Hills section. It also was found to occasionally occur in samples from the Crow Butte section.

Botanical affinities.—Unknown.

Frequency.—"Abundant" to "infrequent."

Genus **AQUILAPOLLENITES** Rouse, 1957

Pollen, N₂, Radforth, N. and Rouse, G. 1954, Canadian Jour. Bot., vol. 32, p. 195, fig. 14.

- Aquilapollenites* Rouse, 1957, Canadian Jour. Bot., vol. 35, p. 370.
Proteaceae ? pollen, Sedova in Pokrovskaja and Stelmak, 1960, Pub. V.S.E.G.-E.I. n.s., vol. 30, p. 324.
Proteaceae ? pollen, Agranovskaia, et al., in Pokrovskaja and Stelmak, 1960, Pub. V.S.E.G.I., n.s., vol. 30, p. 371.
Aquilapollenites Rouse, Chlonova, 1961, Acad. Sci., S.S.S.R., Geol. Geophys. Inst. Pub., No. 7, p. 82.
Taurociphalus Simpson, 1961, Roy. Soc. Edinburgh, Trans., vol. 64, No. 16, p. 440.

Type species.—*Aquilapollenites quadrilobus* Rouse, 1957.

Description.—See Stanley, 1961 b.

Discussion.—In view of the important work by Mtchedlishvili (in Samoilovitch, et al., 1961) on *Aquilapollenites* and related genera, it appears necessary to compare the species described by Stanley (1961 b) with those described by Mtchedlishvili. It is clear that the work by Mtchedlishvili appeared earlier than Stanley (1961 b) and, therefore, this work has priority. Furthermore, it is apparent that at least some of the species described by this writer will have to be put into synonymy. Until the writer can complete the translations of Mtchedlishvili's descriptions, the species described by Stanley (1961 b) are at least temporarily retained.

Dr. Mtchedlishvili has kindly sent this writer several fine photographs of the species of *Aquilapollenites* and related genera described in "Pollen and Spores from the Western Siberia." These photographs were of great value in writing the differential diagnoses on the following pages.

Because many of the photographs in Stanley (1961 b) are low in contrast, photographs of the holotypes or paratypes of the species described in the above paper are included here.

***Aquilapollenites amplus* Stanley, 1961**

Pl. 48, figs. 1-6

Aquilapollenites amplus Stanley, 1961, Pollen et Spores, vol. 3, No. 2, p. 342, pl. 1, figs. 1-6; pl. 2, figs. 1-4; pl. 3, figs. 1-5.

Holotype.—Slide CB 11 (NS) D; USNM#131309; pl. 1, figs. 1-6 (Stanley, 1961).

Isotype.—Slide SCB-14-4; USNM#131310; pl. 2, figs. 1-4 (Stanley, 1961).

Description.—See Stanley, 1961b.

Differential diagnosis.—There are several species of *Aquilapollenites* described by Mtchedlishvili that are close or the same as

this species. These species are *A. granulatus*, *A. asper*, *A. subtilis*, *A. insignis*, and *A. latilobus*.

Occurrence.—*Aquilapollenites amplus* was found to occur only in samples from Zone II of the Crow Butte section.

Frequency.—"Infrequent" to "common."

***Aquilapollenites delicatus* Stanley, 1961**

Pl. 49, figs. 1-4

Aquilapollenites delicatus Stanley, 1961, Pollen et Spores, vol. 3, No. 2, p. 346, pl. 4, figs. 1-12.

Holotype.—Slide SCB-11-20; USNM#131311; pl. 4, figs. 1-5 (Stanley, 1961).

Isotype.—Slide SCB-11-12; USNM#131312; pl. 4, figs. 10-12 (Stanley, 1961).

Description.—See Stanley, 1961b.

Differential diagnosis.—*Aquilapollenites delicatus* Stanley differs from *Mancicorpus senonicum* Mtch. in that it has spines on the body that extend beyond the shorter sculpture elements. These spines appear to be absent in *M. senonicum* Mtch. (see Samoilovitch, *et al.*, 1961, pl. 72, fig. 2c).

Occurrence.—*Aquilapollenites delicatus* was found to occur in Zones I, II, and III of the Crow Butte section.

Frequency.—"Infrequent" to "common."

***Aquilapollenites murus* Stanley, 1961**

Pl. 48, figs. 7-11

Aquilapollenites murus Stanley, 1961, Pollen et Spores, vol. 3, No. 2, p. 347, pl. 5, figs. 1-8; pl. 6, figs. 1-9.

Holotype.—Slide CB (NS) B; USNM#131313; pl. 5, figs. 1-5 (Stanley, 1961).

Isotype.—Slide CB-14-1; USNM#131314; pl. 5, figs. 6-9.

Description.—See Stanley, 1961b.

Differential diagnosis.—This species appears to be identical to *Parviprojectus striatus* Mtch. from the illustrations in Samoilovitch, *et al.* (pl. 73, figs. 1c, 1d) the granular areas at the poles of *P. striatus* are not present in *A. murus*.

Occurrence.—*Aquilapollenites murus* was found to occur in all productive samples from Zone II of the Crow Butte section.

Frequency.—"Infrequent" to "common."

***Aquilapollenites pulvinus* Stanley, 1961**

Pl. 49, figs. 5-9

Aquilapollenites pulvinus Stanley, 1961, Pollen et Spores, vol. 3, No. 2, p. 347, pl. 7; figs. 1-12.

Holotype.—Slide CB-14-2; USNM#131315; pl. 7, figs. 1-4 (Stanley, 1961).

Isotype.—Slide SCB-14-9; USNM#131316; pl. 7, figs. 5-8 (Stanley, 1961).

Description.—See Stanley, 1961b.

Differential diagnosis.—This species most closely resembles *Mancicorpus solidum* Mtch. Here too, the characteristic spines on the prolate portion of the body of *A. pulvinus* appear to be absent on the prolate portion of the body of *M. solidum* (see Mtchedlishvili in Samoilovitch, *et al.*, 1961, pl. 72, figs. 1 b, 1 c; Stanley, 1961 b, p. 348).

Occurrence.—*Aquilapollenites pulvinus* was found to occur only in Zone II of the Crow Butte section.

Frequency.—"Infrequent."

Aquilapollenites reticulatus Stanley, 1961

Pl. 49, figs. 10-14

Aquilapollenites reticulatus Stanley, 1961, Pollen et Spores, vol. 3, No. 2, p. 348, pl. 8, figs. 1-12.

Holotype.—Slide SCB-14-6; USNM#131317; pl. 8, figs. 1-4, (Stanley, 1961).

Isotype.—Slide SCB-14-10; USNM#131318; pl. 8, figs. 5-8 (Stanley, 1961).

Description.—See Stanley, 1961b.

Differential diagnosis.—This species closely resembles *Parviprojectus reticulatus* Mtch. It differs from this latter species in that in *A. reticulatus* Stanley, the reticulate sculpture changes to a striate sculpture near the base of each projection (see Stanley, 1961, p. 348), whereas in *P. reticulatus* Mtch. it does not (see Samoilovitch, *et al.*, 1961, pl. 73, fig. 2c).

Occurrence.—*Aquilapollenites reticulatus* was found to occur in samples from Zone II of the Crow Butte section.

Frequency.—"Infrequent."

Genus **OVOIDITES** Potonie ex Thomson and Pflug, 1953

Ovoidites Potonie, 1951, Palaeontographica, vol. 91, pt. 13, pl. 21, fig. 185.

Ovoidites Potonie ex Thomson and Pflug, 1953, Palaeontographica, vol. 94, pt. B, p. 113.

Ovoidites (Potonie), Krutzsch, 1959, Geologie, vol. 8, Nos. 21, 22, p. 249.

Type species.—*Ovoidites ligneolus* (Potonie), Thomson and Pflug, 1953.

Description.—See specific description below.

Discussion.—There seems to be some overlap between this genus and *Schizosporis* Cookson and Dettmann. As these authors mentioned (1959, p. 213) some forms published by Krutzsch (1957) and assigned to *Ovoidites* may belong in *Schizosporis*. The same situation may be true for Krutzsch's 1959 paper. Cookson and Dettmann (*op. cit.*) wrote that Potonie "is of the opinion that his genus *Ovoidites* is distinct from *Schizosporis*." Just what this distinction is, neither Cookson and Dettmann nor Potonie stated. If a clear cut distinction cannot be made, then perhaps *Schizosporis* should be put into synonymy. For the present, however, the two genera under discussion are treated as separate genera.

Botanical affinities.—Unknown.

Ovoidites ligneolus (Potonie), Thomson and Pflug Pl. 32, figs. 12-13

Sporites ligneolus Potonie, 1931, S.-B. Ges. nat. Freunde, Berlin, No. 1-3, pl. 2, fig. V25a.

Sporites ligneolus Potonie, Potonie and Venitz, 1934, Arb. Inst. Palaeobot., vol. 5, p. 15, pl. 4, figs. 127-128.

Sporites ligneolus Potonie, Wolf, 1934, Arb. Inst. Palaeobot., vol. 5, p. 68, fig. 35.

Sporites ligneolus Potonie, Raatz, 1937, Abb. Preuss. L.-A.N.F., pt. 183, p. 12, figs. 1-3.

Ovoidites ligneolus (Potonie), Potonie, 1951, Palaeontographica, vol. 91, pt. B, pl. 21, fig. 185.

Ovoidites ligneolus (Potonie), Thomson and Pflug, 1953, Palaeontographica, vol. 94, pt. B, p. 113, pl. 15, fig. 100.

Ovoidites ligneolus (Potonie), Krutzsch, 1959, Geologie, vol. 8, Nos. 21-22, p. 250.

Sporites ligneolus Potonie, Kremp and Ames, 1961, Catalog Fossil Spores and Pollen, vol. 14, p. 122.

Description.—Fusiform *incertae sedis*; overall length $72\ \mu$, width $36\ \mu$. Endexine $1\ \mu$ thick; ectexine thickness $1.5\ \mu$; sculpture irregularly reticulate. A fissure, which almost divides the grain in half, is characteristically present.

Discussion.—The detailed subdivision of this species by Krutzsch, 1959 is thought to be unjustified. Undoubtedly, some of the forms assigned to *Ovoidites* by Krutzsch should be assigned to *Schizosporis* Cookson and Dettmann.

Differential diagnosis.—At present there is no clear subdivision of this genus into distinct species.

Occurrence.—*Ovoidites ligneolus* (Potonie), Potonie was found to occur only in samples from the Cannonball section.

Botanical affinities.—Unknown.

Frequency.—"Infrequent."

Genus **PSEUDOTRICOLPITES** Stanley, n. gen.

Type species.—*Pseudotricolpites reticulatis* Stanley, n. sp.

Name derivation.—Named after the false colpi-like apertures present.

Description.—See specific description.

Botanical affinities.—Unknown.

Pseudotricolpites reticulatus Stanley, n. sp.

Pl. 46, figs. 26-33

Holotype.—Slide SCBO-9; location 29.0×112.7 ; Pl. 46, figs. 26-28, 31-33.

Isotype.—Slide SCBO-3; location 46.5×106.5 ; Pl. 46, figs. 29-30.

Type locality.—Crow Butte, Harding Co., South Dakota.

Type horizon.—Hell Creek formation, Maestrichtian.

Name derivation.—*Reticulatus*=netlike; after the finely reticulate sculpture of this species.

Description.—Prolate pseudotricolpate pollen grains; length of equatorial axis 15-18 μ ; diameter 13-16 μ ; shape-class-index approximately 1.1. Endexine about 0.6 μ thick; ectexine elements appear to be clavae that have their distal ends touching to form a reticulate tectum; clavae length 0.6 μ . Two colpi-like indentations extend nearly the length of the pollen grain; often the exine at the base of these indentations may be ruptured forming a tearlike fissure. Typically the exine is ruptured at or near a position where the third colpus would occur in a normal tricolpate pollen grain; at this position the exine is not indented, and normally the rupture is shorter than, and oblique to the two true colpi.

Differential diagnosis.—This species resembles *Eucommiidites troedssonii* Erdtman (see Couper 1958 and especially Hughes, 1961). It differs from that species (and genus) in that it has no well-developed colpus. The one aperture is a tear in the exine that apparently occurs at a predetermined location.

Occurrence.—This species was found to sporadically occur in samples from both the Crow Butte and North Cave Hills sections.

Botanical affinities.—Unknown.

Frequency.—"Infrequent" to "common."

Genus **TRIALAPOLLIS** Stanley, n. gen.

Type species.—*Trialapollis scabratus*, n. sp.

Name derivation.—*Ala*=wing; after the winglike lobes characteristic of this genus.

Description.—See species description.

Differential diagnosis.—See species differential diagnosis.

Botanical affinities.—Unknown.

Trialapollis scabratus Stanley, n. sp.

Pl. 47, figs. 9-17

Holotype.—Slide SCBO-6; location 26.2×110.5 ; Pl. 47, figs. 9-11.

Isotype.—Slide SCBO-7; location 30.0×91.9 ; Pl. 47, figs. 15-17.

Type locality.—Crow Butte, Harding Co., South Dakota.

Type horizon.—Hell Creek formation, Maestrichtian.

Name derivation.—Named after the texture of this new species.

Description.—Prolate trilobed inaperturate pollen grains consisting of a broad central body with three wide but short inaperturate winglike projections; size of body $12-18 \mu \times 21-24 \mu$. Wings broadly attached along entire length of body; length of wing about 6μ . Exine of body distinctly two layered with endexine less than 0.3μ thick whereas ectexine is about 0.5μ thick; the exine of the wings appears to thin distally; texture of both body and wings is scabrate.

Discussion.—The long axis of the body is here considered to be the polar axis; about this axis, the three winglike lobes are then radially arranged.

Differential diagnosis.—*Trialapollis scabratus*, n. sp. resembles several other described genera. It differs from genera such as *Aquilapollenites* Rouse, *Latipollis* Krutzsch, and *Triporina* Chlo-nova by lacking any type of pore or aperture at the distal extremity of the wing or in the axis of the wing. It may be that this species (and genus) is in someway related to the above mentioned genera. This will have to await further investigation.

Occurrence.—This species was found to be restricted to the lower most part of Zone III of the Crow Butte section.

Frequency.—"Infrequent."

Genus **TRIATRIOPOLLENITES** Pflug, 1953

Triatriopollenites Pflug, 1952, Palaeont. Z., vol. 26, Nos. $\frac{1}{2}$, p. 117.

Triatriopollenites Pflug in Thomson and Pflug, 1953, *Palaeontographica*, vol. 94, pt. B, p. 76.

Triatriopollenites Pflug, Potonie, 1960, *Beih. Geol. Jb.*, vol. 39, p. 119.

Type species.—*Triatriopollenites rurensis* Pflug and Thomson in Thomson and Pflug, 1953.

Description.—Oblate tricolporate pollen grains; outline in polar view subround to subtriangular with pores apically located. Size and sculpture variable. Pores bear a distinct atrium.

Differential diagnosis.—The presence of a distinct atrium separates this organ genus from other similar organ genera.

Botanical affinities.—After Potonie (1960, p. 119) "Myricaceae (in particular *Myrica*?)." It is not believed that the species assigned to *Triatriopollenites* Pflug in this work has any affinities to Myricaceae or *Myrica*.

Triatriopollenites pseudomagnificus Stanley, n. sp. Pl. 47, figs. 1-8

Holotype.—Slide SCB 11-17; location 31.6×113.2 ; Pl. 47, figs. 1-4.

Isotype.—Slide SCB 12-7; location 37.7×101.2 ; Pl. 47, figs. 5-6.

Type locality.—Crow Butte, Harding Co., South Dakota.

Type horizon.—Hell Creek formation, Maestrichtian.

Name derivation.—Named after the superficial resemblance to *Thomsonipollis magnificus* Krutzsch, 1960.

Description.—Oblate triporate pollen grains; outline in polar view subtriangular; equatorial diameter $25-40 \mu$. Exine three layered, consisting of an endexine with a thickness of about 0.5μ , a mesine (?) with a thickness of 1μ in the areas between the pores and increases in thickness to about 3.5μ in the pore region forming a tumescens. The third layer, the ectexine, is 1μ thick. Sculpture reticulate with randomly arranged, elongated lumina. Pores simple in construction, consists of an atrium and a tumescens; pore outline more or less circular with a diameter of 4μ .

Differential diagnosis.—At first glance, *Triatriopollenites pseudomagnificus*, n. sp. appears to resemble *Thomsonipollis magnificus* Krutzsch. Careful examination of the pore structure reveals that the construction in *T. pseudomagnificus*, n. sp. is relatively simple whereas in *T. magnificus* Krutzsch it is fairly complex (see

Krutzsch, 1960 for fine detailed drawings of the pore structure in *Thomsonipollis*).

Occurrence.—*Triatriopollenites pseudomagnificus*, n. sp. was found to occur only in samples from Zone II of the Crow Butte section.

Botanical affinities.—Unknown.

Frequency.—"Infrequent."

Genus **TRICOLPITES** Cookson ex Couper, 1953

Tricolpites Cookson, 1947, B.A.N.Z. Antarctic Res. Expedition, Rep. Ser. A, vol. 2, p. 134.

Tricolpites Erdtman, 1947, Sv. Bot. Tidskr., vol. 41, p. 109.

Tricolpites Cookson ex Couper, 1953, New Zealand Geol. Sur. Paleont. Bull., No. 22, p. 61.

Gunnerites Cookson and Pike, 1954, Australian Jour. Bot., vol. 2, No. 2, p. 201.

Tricolpites ex Couper emended Potonie, 1960, Beih. Geol. Jb., vol. 39, p. 95.

Type species.—*Tricolpites reticulatus* Cookson; subsequent designation by Couper, 1953.

Description.—Spherical to oblate tricolpate pollen grains; size moderate to large. Exine sculpture variable. Colpi long, usually gapping.

Discussion.—A species is assigned to this genus that would not ordinarily be placed here if Potonie's 1960 emendation of the genus were followed. Rather than create a new organ genus at this time, Couper, 1953 circumscription of the genus is here followed.

Differential diagnosis.—The spherical to oblate shape of the pollen separate this genus from other tricolpate organ genera.

Tricolpites bathyreticulatus Stanley, n. sp. Pl. 47, figs. 18-23

Holotype.—Slide 18-3-3; location 26.9×102.0 ; Pl. 47, figs. 18-19.

Isotype.—Slide 18-3-11; location 26.0×108.3 ; Pl. 47, figs. 22-23.

Type locality.—Southern half of sect. 24, T. 23 N., R. 9 E., Harding Co., South Dakota.

Type horizons.—Cannonball member, Fort Union formation, Paleocene.

Name derivation.—*Bathy*=deep; *reticulatus*=netlike; after the large lumina present in this species.

Description.—Oblate tricolpate pollen grains, outline in polar

view circular with colpi gapping. Endexine less than $0.5\ \mu$ thick; ectexine reticulate with lumina irregular and up to $3\ \mu$ in diameter; muri about $1\ \mu$ high. Colpi straight, open; apocolpium moderate.

Differential diagnosis.—*Tricolpites bathyreticulatus*, n. sp. is differentiated from *Pollenites willrathae* Potonie by its smaller size and finer reticulation and from *T. reticulatus* Cookson by its larger lumina.

Occurrence.—*Tricolpites bathyreticulatus*, n. sp. was found to occur in samples 1-11 and 1-17 of the North Cave Hills section and in sample 18-3 in the Cannonball section.

Botanical affinities.—*Fraxinus*?. *Tricolpites bathyreticulatus*, n. sp. somewhat resembles *Fraxinus excelsior* L. (see Praglowski, 1962, pl. 22). This new species even more closely resembles pollen described and assigned to *Bucklandia* by Simpson (1961).

Frequency.—"Infrequent."

Tricolpites hians Stanley, n. sp.

Pl. 47, figs. 24-27

Holotype.—S-1-18-8; location 44.1×93.5 ; Pl. 47, fig. 24.

Isotype.—1-18 m-1; location 34.5×91.7 ; Pl. 47, fig. 25.

Type locality.—North Cave Hills, Harding Co., South Dakota.

Type horizon.—Ludlow member, Fort Union formation, Paleocene.

Name derivation.—*Hio*=gapping; after the gapping colpi of this species.

Description.—Oblate tricolpate pollen grains; outline in polar view circular with an equatorial diameter of $18-20\ \mu$. Endexine and ectexine each about $0.5\ \mu$ thick; ectexine elements consist of muri forming a reticulum with lumina approximately $0.2-0.3\ \mu$ wide. Colpi long, straight, and open, apocolpium moderate.

Differential diagnosis.—This species differs from most similar fossil pollen grains described by being smaller in size. It differs from *Pollenites ortholaesus* Potonie by having a much thinner exine and from *P. ventosus* Potonie by its more open colpi and its smaller apocolpium.

Occurrence.—*Tricolpites hians*, n. sp. was found to occur only in samples from the lower portion of Zone I of the North Cave Hills section.

Botanical affinities.—Unknown.

Frequency.—"Infrequent."

Tricolpites parvus Stanley, n. sp.

Pl. 47, figs. 28-31

Holotype.—Slide G 1-7-1; location 27.3×106.5 ; Pl. 47, figs. 30-31.

Isotype.—Slide G 1-11-1; location 36.4×111.6 ; Pl. 47, figs. 28-29.

Type locality.—North Cave Hills, Harding Co., South Dakota.

Type horizon.—Ludlow member, Fort Union formation, Paleocene.

Name derivation.—*Parvus*=little; after the small lumina present in specimens of this species.

Description.—Oblate tricolpate pollen grain; outline in polar view circular; equatorial diameter $18-25 \mu$. Endexine about 1μ thick; ectexine finely reticulate with lumina approximately 0.3μ wide and muri about 0.5μ high. Colpi straight, gapping; apocolpium moderate.

Differential diagnosis.—*Tricolpites parvus*, n. sp. is differentiated from *T. reticulatus* Cookson by its somewhat smaller size. Cookson mentioned that her species is finely reticulate, but she does not mention the size of the lumina.

Occurrence.—*Tricolpites parvus* Stanley, n. sp. was found to occur only in the upper part of Zone I of the North Cave Hills section.

Frequency.—"Infrequent."

Genus **WODEHOUSEIA** Stanley, 1961

Indefinite forms, Agranovskaia, *et al.*, in Pokrovskaia and Stelmak, 1960, Pub. V.S.E.G.E.I., new series, vol. 30, p. 396, figs. 23, 24.

Wodehouseia Stanley, 1961, Pollen et Spores, vol. 3, No. 1, p. 156.

Kryshtofoviana Samoilovitch, 1961, Pollen and Spores from Western Siberia, p. 232.

Regina Samoilovitch, 1961, Pollen and Spores from Western Siberia, p. 240.

Deplexipollis Chlonova, 1961, Acad. Sci., S.S.S.R., Geol. Geophys. Inst., Pub. No. 7, p. 81.

Deplexipollis Chlonova, Chlonova, 1962, Pollen et Spores, vol. 4, No. 2, p. 306.

Type species.—*Wodehouseia spinata* Stanley, 1961

Description.—See Stanley, 1961b.

Botanical affinities.—In 1961 when this genus was first des-

cribed by the writer its natural affinities were stated (Stanley, 1961a, p. 157) as being "unknown." Furthermore, it was stated (*op. cit.*) that "it is entirely possibly that *Wodehouseia* may have zoological rather than botanical affinities." Examination of samples from the marine Cannonball member yield no specimen assignable to *Wodehouseia* tending to rule out any marine planktonic organism. The occurrence of specimens in only continental sediments do not eliminate the possibility of a zoological affinity inasmuch as the habitat could be limnitic. However, a botanical affinity, belonging to either the algae or belonging to the higher plants is still a possibility. Its wide spread occurrence in certain strata in the north-western Great Plains and, as pointed out by Chlonova (1962, p. 308), in northern Asia tend to suggest, though not prove, botanical affinities for this genus.

Discussion.—Dr. Sofia Samoilovitch, along with a written communication (Jan. 27, 1963), sent some fine photographs to the author. From these photographs, (1961) it appears that *Regina excelsa* Samoilovitch is a synonym of *Wodehouseia spinata* Stanley and the genus *Kryshtofoviana* Samoilovitch as synonym of *Wodehouseia* Stanley. Dr. Samoilovitch (written communication mentioned above) is in full accordance with this. She would, however, like to maintain *Regina* Samoilovitch as a separate genus distinct from *Wodehouseia*. Dr. Samoilovitch would place the genera *Wodehouseia* (*Kryshtofoviana*), *Regina*, *Singularia*, and *Azonia* all under the "super-genus" *Kryshtofoviacites* as she has done in her 1961 monograph. Because as Dr. Samoilovitch is dealing with many more species than this writer, it appears that she may be correct in this subdivision. At present, in the United States, there are only two species recognized and, therefore, in this paper they are retained under the genus *Wodehouseia*. Probably at some very near future date, *Wodehouseia fimbriata* may have to be removed from *Wodehouseia* and transferred to *Regina* Samoilovitch.

***Wodehouseia fimbriata* Stanley, 1961**

Wodehouseia fimbriata Stanley, 1961, Pollen et Spores, vol. 3, No. 1, p. 160, pl. 2, figs. 1-8.

Regina excelsa Samoilovitch, 1961, Pollen and Spores from Western Siberia, p. 240, pl. 77, figs. 1a-f.

Holotype.—Slide 1-18 (NS) F; pl. 2, figs. 1-3 (Stanley, 1961a).

Isotypes.—Slide 1-18 (NS) F; S-1-18-2S; pl. 2, fig. 4 Stanley, 1961a).

Description.—See Stanley, 1961a.

Occurrence.—*Wodehouseia fimbriata* was found to occur in samples from the lower portion of Zone I and the upper portion of Zone II of the North Cave Hills section and in samples from the Twin Buttes section.

Frequency.—"Infrequent."

***Wodehouseia spinata* Stanley, 1961**

Wodehouseia spinata Stanley, 1961, Pollen et Spores, 1961, vol. 3, No. 1, p. 157, pl. 1, figs. 1-12.

Kryshstofoviana vera Samoilovitch, 1961, Pollen and Spores from Western Siberia, p. 233, pl. 75, figs. 1a-d, 2, 3a-c.

Holotype.—Slide CB-11 (NS) A; pl. 1, figs. 1-3, (Stanley, 1961a).

Isotypes.—Slide CB-11 (NS) C; slide S-8-1a-10S; pl. 1, figs. 4-6, (Stanley, 1961a).

Description.—See Stanley, 1961a.

Occurrence.—*Wodehouseia spinata* was found to occur in samples throughout Zones I and II of the Crow Butte section.

Frequency.—"Common."

APPENDIX

DESCRIBED SECTIONS

NORTH CAVE HILLS SECTION

When the Ludlow member of the Fort Union formation was designated, no type section was named and only a type area, near the town of Ludlow, Harding County, South Dakota, was given. The measured sections given below include the Ludlow member of the Fort Union formation and also, for completeness, the overlying Tongue River member of the Fort Union formation.

The thickness of the Ludlow member, if subsections I, B, D and E, are included is about 325 feet. This thickness is fairly close to the 350 feet for the maximal thickness for this member. The complete composite section here is considered to be Tertiary (Paleocene). Plant microfossil evidence supports this conclusion.

The measured sections are located in a gully at the southeastern part of the North Cave Hills butte at NE 1/9, sec. 13, T. 21 N., R. 5. E., Harding County, South Dakota.

SUBSECTION 1

Sample Number	Lithologic Description	Thickness in Feet	
		Bed	Total
	Covered to top of butte	17.0	493.1
1-100	Sandstone, fine-grained, white, cross-bedded, poorly cemented; sample 1-100 was collected 2 feet above the base.	6.5	476.1
	Gradation zone	0.5	469.6
1-101	Sandstone, very fine to fine-grained, red-brown, cross-bedding present with very fine-grained sandstone making up the foreset beds; sample 1-101 was collected 2 feet from top.	24	469.1
1-103	Siltstone, white, hard, clayey, in beds up to 1 1/2 feet thick, alternating with light gray, finely laminated siltstone in beds up to 4 inches thick; sample 1-102, white siltstone; sample 1-103, light gray siltstone	30	445.1
1-102	Sandstone, very fine-grained, yellow, slightly cross-bedded, highly pitted, few lamina of a red-brown sandstone present; cap-rock and cliff-former of butte.	10	415.1
	Sandstone, very fine-grained, yellow, contains lamina of red-brown fine-grained sandstone, cliff-former	14	405.1
	Sandstone, very fine-grained, yellow, weathers yellow-brown, slightly cross-bedded, cross-bedding more common toward base; contains thin lenses of very fine-grained red sandstone	28	391.1
1-1	Sandstone, fine-grained, red-brown, some ironstone present as nodules.	1	363.1
1-2	Sandstone, fine-grained, yellow; contains thin lenses of brown clay	3.5	362.1
1-3	Sandstone, fine-grained, yellow; lenses of brown clay absent	7.5	358.6
	Sandstone, fine to medium-grained, white	9	351.1
	Ironstone zone	0.2	342.1
	Sandstone, fine to medium-grained, white	4	341.9
	Sandstone, fine-grained, yellow	0.2	337.9
	Sandstone, fine to medium-grained, yellow, cross-bedded	8	337.7
	Ironstone zone	0.1	329.7
1-4	Sandstone, very fine-grained, white, interbedded with a fine-grained yellow sandstone, yellow sandstone beds up to several foot thick.	18	329.6
	Contact of Ludlow-Tongue River members, Fort Union formation		
	Sandstone, fine-grained, gray	30	311.6
1-5	Clay, black	0.2	281.6
	Sandstone, fine to medium-grained, gray	13.6	281.4
1-6	Clay, black	1.5	267.8
	Sandstone, fine to medium-grained, gray	7	266.3
1-7	Lignite, very friable; red clay at base	0.3	259.3
	Sandstone, fine to medium-grained, gray	10	259.0
1-8a	Lignite, very blocky; divided into three 1 1/2 foot parts for sampling	4.5	249.0
1-8b			
1-8c	Mudstone, red-brown	4	244.5

1-9	Lignite	0.2	240.5
	Sandstone, very fine-grained, brown, clayey	2	240.3
	Sandstone, very fine-grained, white, poorly cemented	4	238.3
	Sandstone, very fine-grained, yellow-brown, clayey	5	234.3
1-10	Clay, red-brown	3	229.3
	Sandstone, very fine-grained, yellow-brown, clayey	3	226.3
1-10-1	Sandstone, fine-grained, white, calcareous; ledge-former	1	223.3
	Clay, gray, sandy	4	222.3
	Mudstone, red-brown	4	218.3
1-11	Lignite	0.2	214.3
	Sandstone, very fine-grained, yellow-brown	3	214.1
1-11-1	Sandstone, very fine-grained, white, calcareous, ripple marks? present	1	211.1
	Sandstone, very fine-grained, yellow-brown, clayey	9	210.1
	Clay, gray	1	201.1
1-12a	Lignite, blocky, contains large fragments of wood-like material; divided into two 1 ¼ foot parts for sampling	2.5	200.1
1-12b	Sandstone, fine to medium-grained, gray; interbedded with thin beds of gray plastic clay	90	197.6
1-13	Clay, gray, plastic	2	107.6
1-13a	Lignite, very friable	0.2	105.6
	Clay, gray, plastic	0.2	105.4
1-13b	Lignite, very blocky, especially at base, friable in the uppermost six inches; divided into three 1 foot parts and one 1 ½ foot part for sampling, the 1 ½ foot sample is at the base	4.5	105.2
1-13c	Sandstone, medium-grained, gray, interbedded with gray plastic clay	18	100.7
1-13d	Lignite, very friable in the uppermost foot and becoming blocky toward base; divided into three equal parts for sampling	3	82.7
1-13e	Clay, gray, plastic	3	79.7
1-14a	Clay, black, almost lignitic in appearance	0.2	76.7
1-14b	Sandstone, medium to fine-grained, gray	11	76.5
1-14c	Clay, gray, plastic	1	65.5
1-15	Lignite, slightly blocky throughout, except in the upper two inches where it is fissile-like; divided into three equal parts for sampling	3.3	64.5
1-16a	Clay, gray, plastic	1	61.2
1-16b	Sandstone, medium to fine-grained, yellow-brown; some thin beds of gray plastic clay present	20	60.2
1-16c	Lignite, very friable at top and slightly blocky at base	0.7	40.2
1-17	Sandstone, fine-grained, yellow, clayey; color boundary placed at base of this sandstone unit	8	39.5
1-18	Lignite, friable	0.3	31.5
	Clay, gray, plastic	2	31.2
1-18-1	Sandstone, medium-grained, white; (same sandstone from which E-13 was collected)	1.5	29.2
	Sandstone, fine to medium-grained, gray	21	27.7
1-19	Lignite	0.2	6.7
	Sandstone, medium to fine-grained, gray	2	6.5
1-20a	Lignite, friable at top and becoming very blocky and hard toward the base; divided into two equal parts for sampling	1.5	4.5
1-20b	Sandstone, fine to medium-grained, gray	2	3
1-22a	Lignite; divided into two equal parts for sampling	1	1
1-22b			

SUBSECTION E

Sample Number	Lithologic Description	Thickness in Feet	
		Bed	Total
E-13	Sandstone, medium-grained, white, (same sandstone from which sample 1-18-1 was collected)	1.5	16.8
E-12	Sandstone, very fine-grained, yellow-brown; E-12 taken near base	6.5	15.3
E-11	Lignite, earthy; divided into two $\frac{1}{4}$ foot parts for sampling	0.5	8.8
E-10	Clay, gray, very plastic	1	8.3
E-9	Sandstone, very fine-grained, brown, slightly clayey; E-8 taken near base	0.6	7.3
E-8	Lignite; divided into two equal parts for sampling	0.6	6.7
E-7			
E-6			
E-5	Clay, gray, plastic	1	6.1
E-4	Lignite; divided into two equal parts for sampling	0.6	5.1
E-3			
	Clay, gray, very plastic	0.5	4.5
E-2	Sandstone, very fine-grained, clayey, dark-brown	3	4.0
E-1	Clay, dark-brown; contains black clay stringers; this clay is thought to be equivalent to the upper lignite in section D (sample D-14)	1	1.0

SUBSECTION D

Sample Number	Lithologic Description	Thickness in Feet	
		Bed	Total
D-15	Clay, brown, plastic	0.1	12.2
D-14	Lignite	0.1	12.1
D-13	Sandstone, very fine-grained, brown	0.1	12.0
D-12	Lignite; divided into two equal parts for sampling	0.2	11.9
D-11			
D-10	Clay, red-brown, plastic	0.1	11.7
D-9	Clay, gray, very plastic	1	11.6
D-8	Sandstone, very fine-grained, brown, clayey	6	11.5
D-7	Clay, dark-brown	0.2	5.5
	Sandstone, very fine-grained, brown, clayey	1.5	5.3
D-6	Clay, brown, very plastic; D-6 taken near base	2	3.8
D-5			
D-4	Lignite; divided into four equal parts for sampling	0.3	1.8
D-3			
D-2			
D-1	Sandstone, very fine-grained, brown	1.5	1.5

SUBSECTION B

Sample Number	Lithologic Description	Thickness in Feet	
		Bed	Total
	Covered, to top of bluff	15	31.5
	Sandstone, very fine-grained, brown, with lenses of very fine-grained yellow sandstone (same unit as the lower sandstone in subsection D).	1.5	16.5
B-12			
B-11	Lignite, earthy; divided into four equal parts for sampling	0.3	15.0
B-10			
B-9			

B-8	Sandstone, very fine-grained, gray, clayey; contains		
B-7	lenses of very fine-grained yellow-brown sandstone; sandstone becomes clayey toward top and is a gray clay at the base of the lignite	5	14.7
B-6	Sandstone, very fine-grained, yellow-brown	3	9.7
B-5	Clay, black	0.1	6.7
B-4	Clay, gray, very plastic	2.5	6.6
B-3	Iron stone zone	0.1	4.1
B-2	Sandstone, very fine-grained, brown	2	4.0
B-1	Sandstone, very fine-grained, yellow-brown; interbedded with gray clay	2	2.0

TWIN BUTTE SECTION

The section at Twin Butte is thought by some workers to contain the Cretaceous-Tertiary boundary and, therefore it was sampled. Twin Butte is located at NC 1/9, sec. 10, T. 19 N. R. E. 6 Harding County, South Dakota.

Sample Number	Lithologic Description	Thickness in Feet	
		Bed	Total
	Sandstone, medium-grained, gray	11	111.1
	Sandstone, medium to fine-grained, interbedded with laminae of red clay	6	100.1
TW-13	Lignite	0.3	94.1
	Claystone, red	2	93.8
TW-12	Clay, brown-black	0.3	91.8
	Sandstone, medium-grained, gray	3	91.5
	Shale, gray	6	88.5
TW-11	Lignite	0.3	82.5
	Covered	21	82.2
TW-10	Lignite	0.3	61.2
	Clay, red-brown	1	60.9
TW-9			
TW-8	Lignite, divided into two parts for sampling	2	59.9
	Shale, gray	3	57.9
TW-7	Clay, black	0.3	54.9
	Shale, red	2	54.6
TW-6	Lignite	0.3	52.6
	Shale, red	2	52.3
TW-5	Lignite	0.3	50.3
	Covered	12	50.0
TW-4	Lignite	0.7	38.0
	Covered	24	37.3
TW-3	Lignite, badly weathered	0.3	13.3
	Covered	6	13.0
TW-2	Lignite, badly weathered	0.2	7.0
	Covered	6	6.8
TW-1	Lignite	0.8	0.8

CROW BUTTE SECTION

The Hell Creek formation was sampled at Crow Butte, in

southcentral Harding County, South Dakota. The type Hell Creek section is in Montana which puts it outside of the study area. The Crow Butte locality was suggested by Dr. Bruno Petsch, of the South Dakota Geological Survey, as a fairly certain Hell Creek outcrop.

The total thickness of the sediments at Crow Butte is some 212 feet which is just about one-half of the usually quoted Hell Creek maximal thickness.

Crow Butte is located at SE $\frac{1}{4}$ section 30 and NE $\frac{1}{4}$ section 31, T. 15 N., R. 5 E., Harding County, South Dakota. The Butte lies a short distance westward from U.S. Highway 85.

Sample Number	Lithologic Description	Thickness in Feet	
		Bed	Total
	Covered, to top of butte	52	212.4
	Clay, light gray, sandy; with lenses of fine-grained yellow sandstone	8	160.4
8-1	Clay, dark-brown	2	152.4
	Clay, light-gray, plastic; becoming slightly sandy toward the top	13	150.4
	Clay, brown; with fine-grained yellow-brown sandstone lamina	1	137.4
8-2	Clay, light gray, plastic	1	136.4
CB-17	Clay, dark-brown	1.5	135.4
CB-16	Clay, gray, very plastic	4	133.9
CB-15a	Clay, red-brown, silty	2	129.9
	Clay, gray, plastic	12	127.9
	Sandstone, medium-grained, yellow; contains several thin beds of finely-laminated red-brown clay	14.5	115.9
CB-15b	Siltstone, red-brown, very finely laminated;	0.5	101.4
	Sandstone, fine-grained, yellow-brown	2	100.9
CB-14	Mudstone, red-brown; contains black clay stringers,		
CB-13	sample CB-12 black clay, CB-11, 13, 14, red-		
CB-12	brown mudstone	1.5	98.9
CB-11	Sandstone, fine-grained, white; interfingers with a		
CB-8	fine-grained yellow-brown sandstone; about five		
CB-9	zones of fine-grained white, calcareous sandstone		
	lenses present; sample CB19 from lenses, sample		
	CB-8 from white sandstone bed	13	97.4
CB-10	Clay, gray, alternating with dark-brown clay and a		
	medium-grained white sandstone	13	84.4
	Gradation zone	2	71.4
CB-7	Sandstone, fine-grained, white, calcareous; contains		
	stringers of black clay, sample CB-7	14	69.4
	Ironstone nodule zone	1	55.4
	Sandstone, fine-grained, white, cross-bedded	11	54.4
	Clay, dark-gray	6	43.4
	Clay, light-gray	3	37.4
	Ironstone nodule zone	1	34.4
CB-6	Sandstone, very-fine-grained, yellow-brown, poorly		
	cemented, slightly cross-bedded	11	33.4
	Mudstone, dark-brown; contains lenses of finely		
	laminated brown clay	7	22.4

CB-5	Sandstone, fine-grained, white, contains lenses of		
CB-4	fine-grained white, calcareous sandstone; sample		
	CB-5 from lenses, sample CB-4 from bed	8	15.4
CB-2	Mudstone, dark-brown; contains lenses of finely		
CB-1	laminated brown clay; sample CB-1 and CB-2		
	from clay lenses	6	7.4
	Ironstone zone	0.6	1.4
CB-3	Clay, gray	0.3	0.8
CB-0	Clay, dark-brown, very finely laminated	0.5	0.5

CANNONBALL SECTION

The Cannonball member of the Fort Union formation was sampled in the northeast side of the North Fork, Grand River which flows through the southern half of sec. 24, T. 23 N., R. 9 E., Harding County, South Dakota. Winchester, *et al.* (1916, p. 22) reported that at the type locality on the Cannonball River, Morten County, North Dakota, 300-350 feet of marine sediments are exposed. These marine sediments thin westward as they interfinger with Ludlow lignitic member of the Fort Union formation. At the locality in Harding County, South Dakota, only a little over 81 feet of sediments were exposed and, as shown by the marine microplankton evidence, only some 47 feet of sediment at this section are marine and assignable to the Cannonball member. The under and overlying nonmarine sediments are referable to the Ludlow member of the Fort Union formation.

Sample Number	Lithologic Description	Thickness in Feet	
		Bed	Total
	Sandstone, yellow-brown, poorly cemented	8	81.6
18-1	Sandstone, yellow-brown with carbonaceous layers; sample 18-1 taken from upper 2 inch part where the carbonaceous layers were more abundant	1.5	73.6
	Sandstone, yellow-brown	3	72.1
18-2	Clay, blue-gray	0.5	69.1
	Sandstone, yellow-brown	7	68.6
18-3	Clay, blue-gray	0.6	61.6
	Sandstone, yellow-brown with some clay	15	61
	Limestone, appears not to be continuous	3	46
	Sandstone, yellow-brown with some clay	18	43
18-4	Clay, blue-gray	3	25
	Sandstone, yellow-brown	20	22
18-5, 5a	Shale, carbonaceous with some thin lignite; lignite more abundant at base	2	2
	Creek bed; North Fork, Grand River		0

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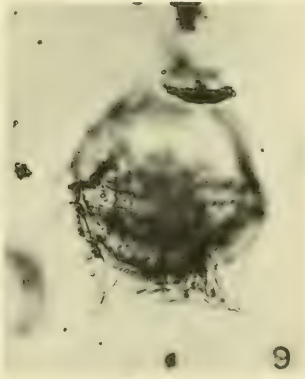
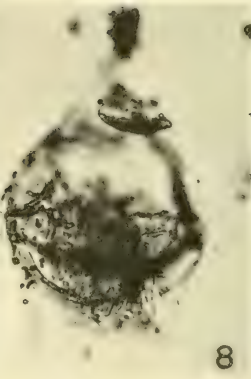
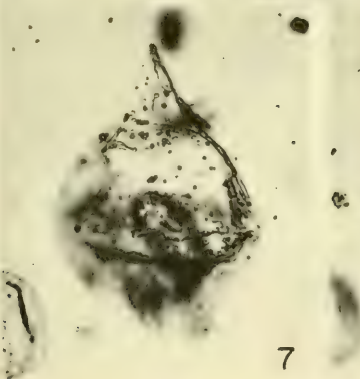
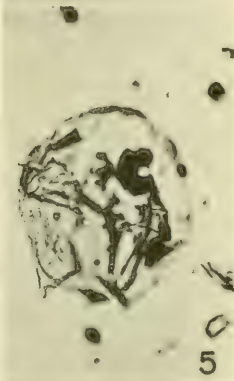
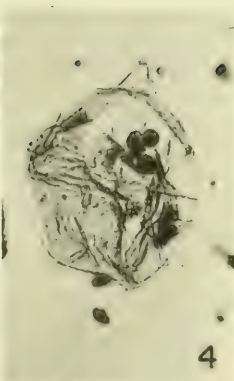
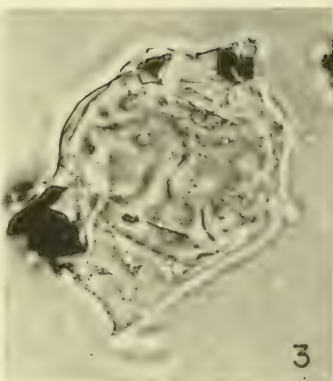
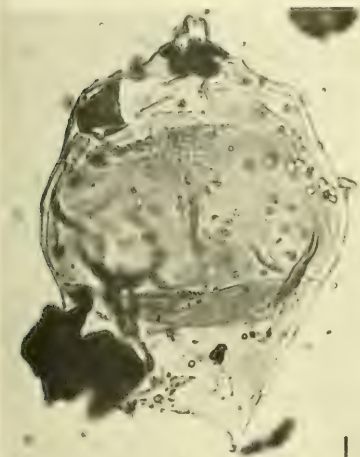
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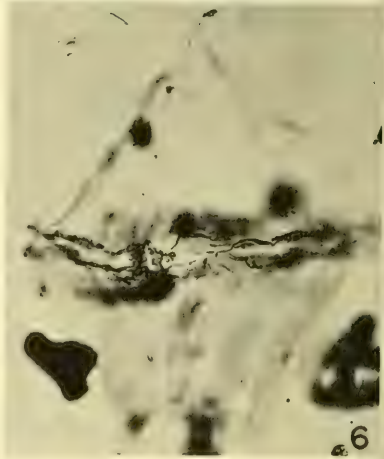
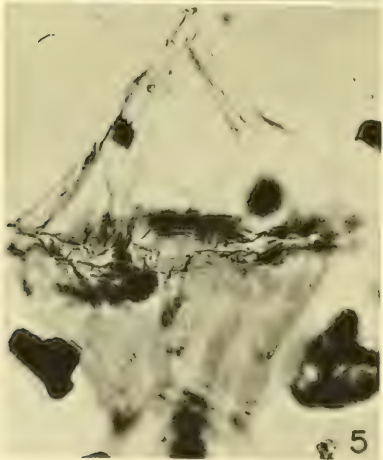
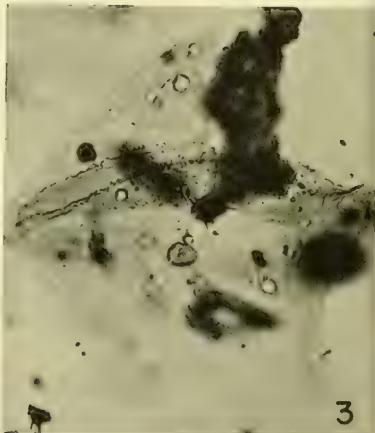
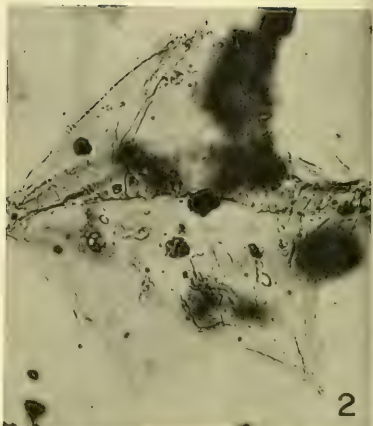
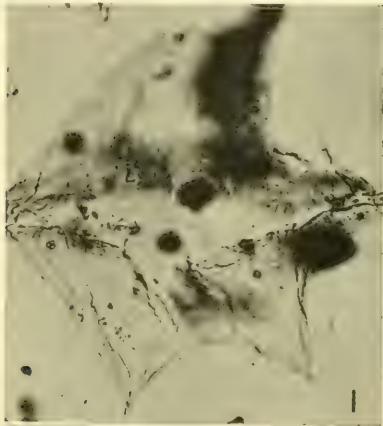
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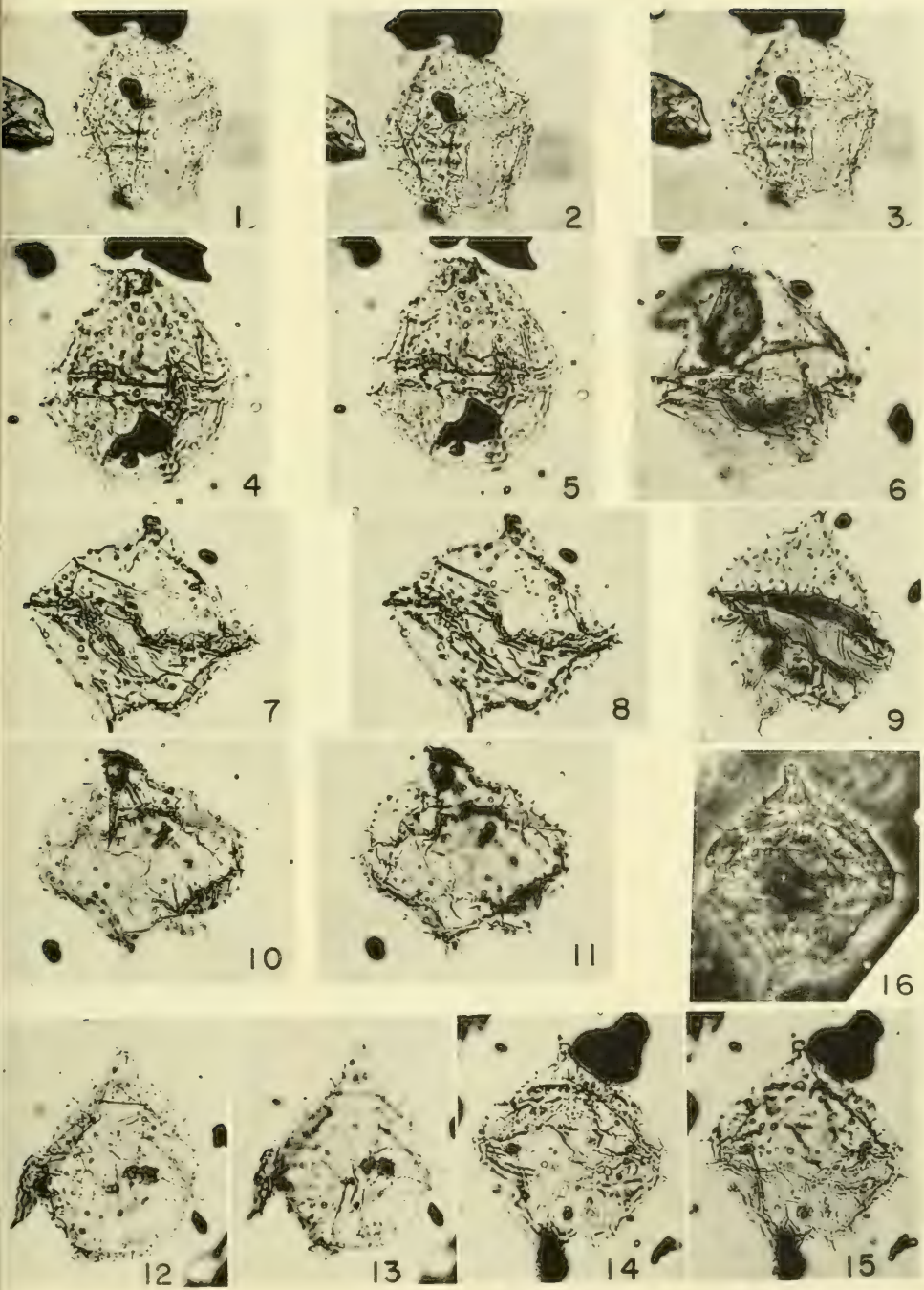
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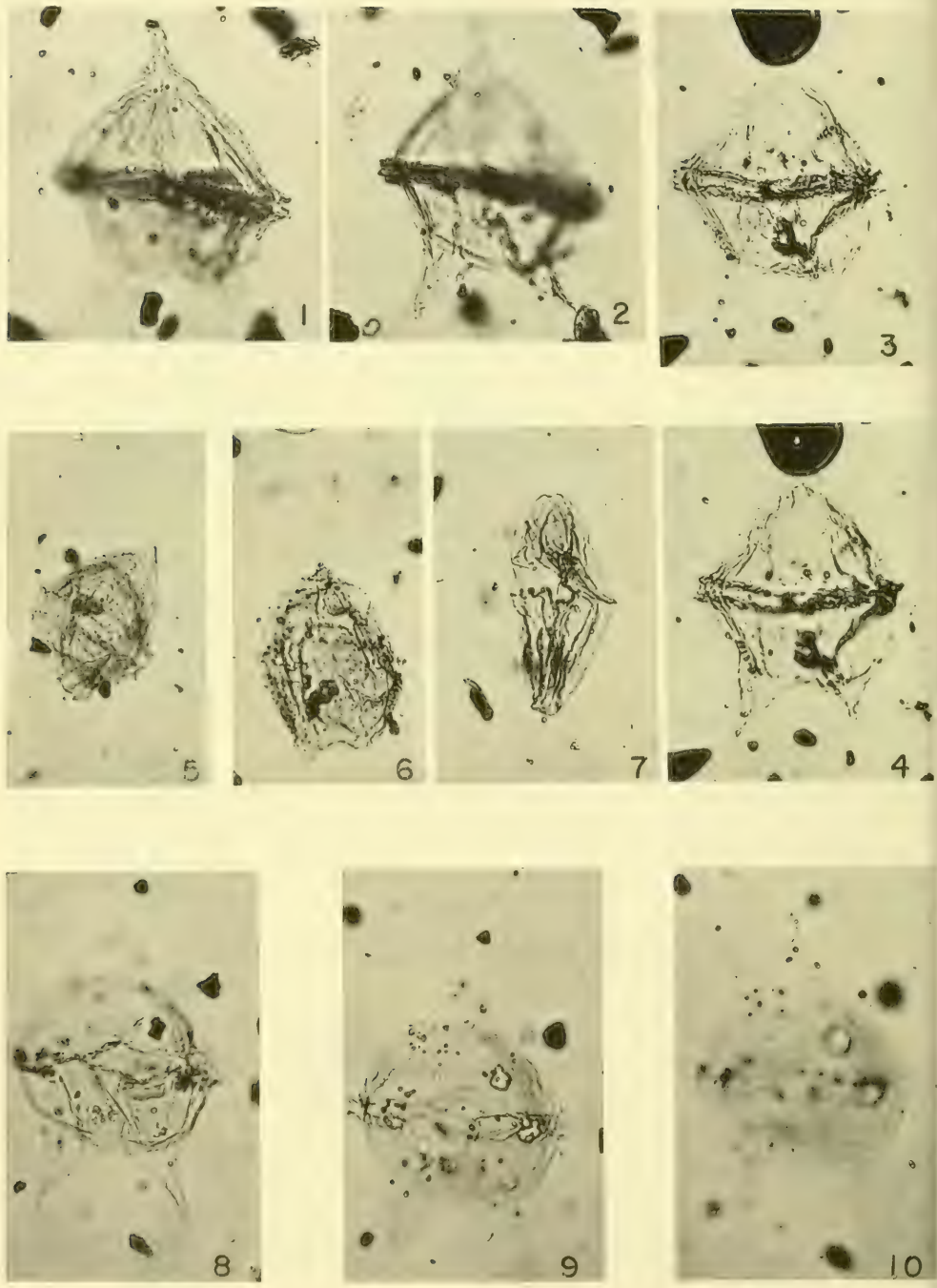
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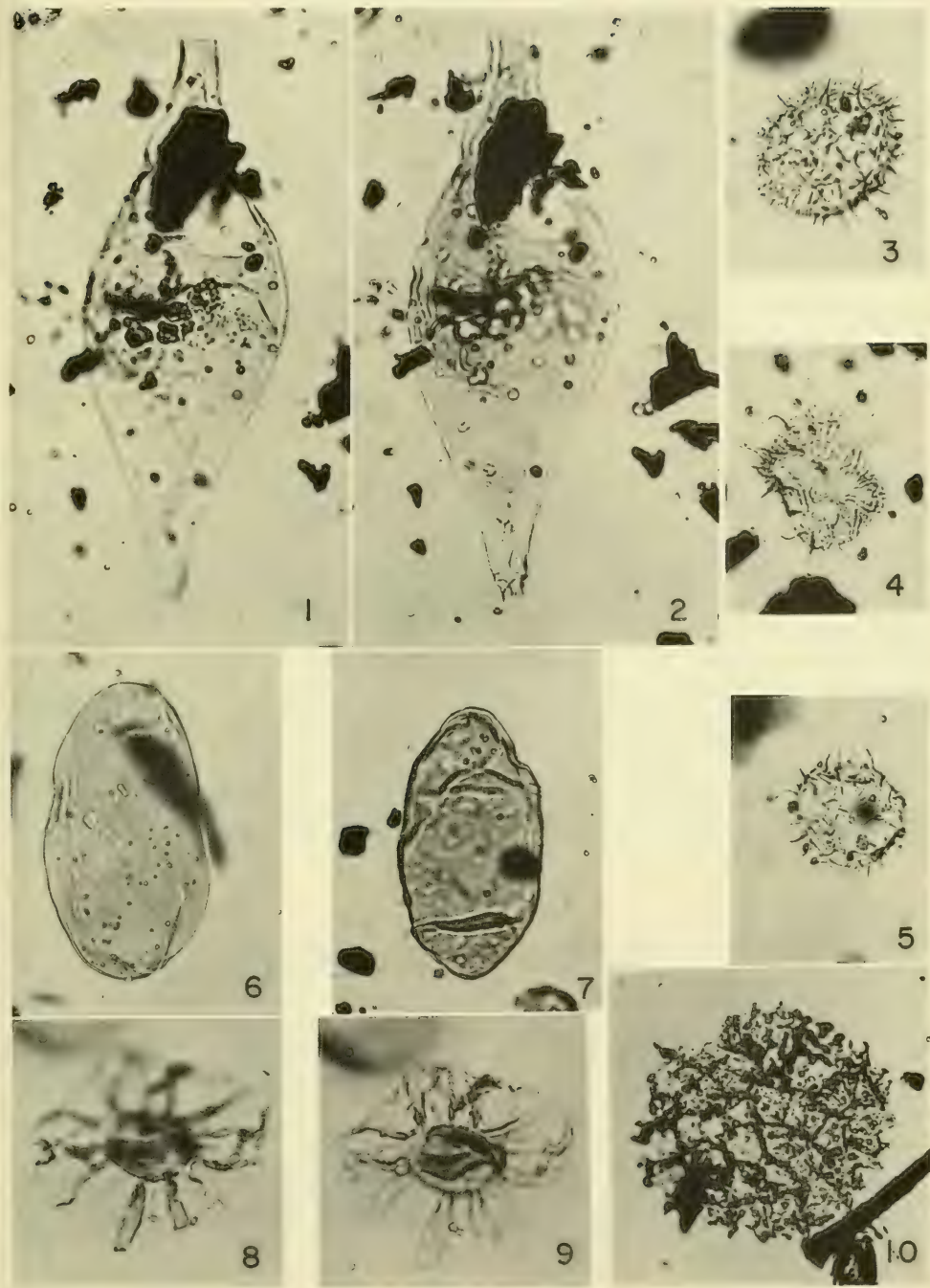
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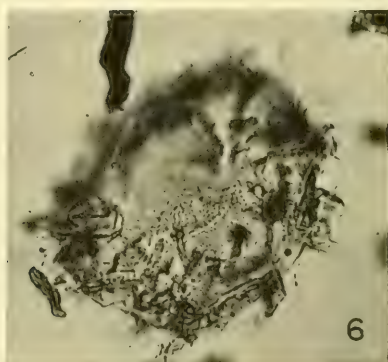
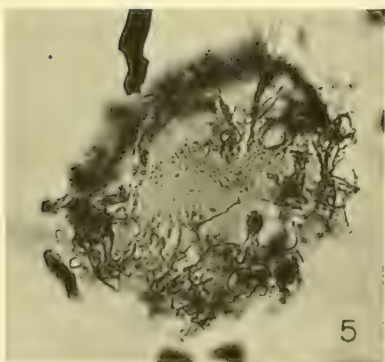
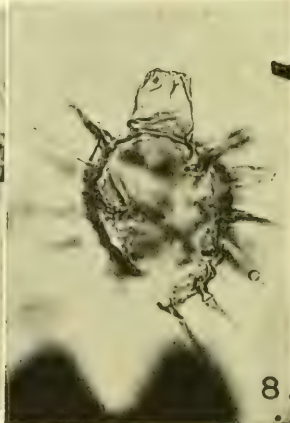
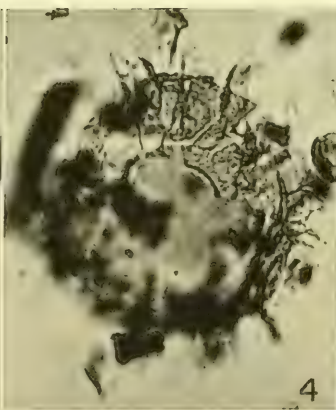
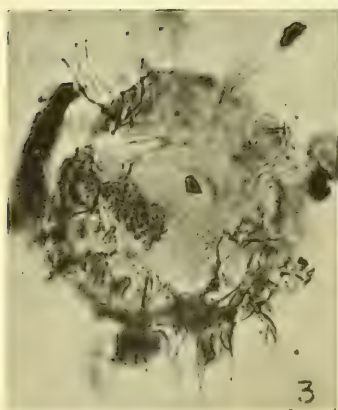
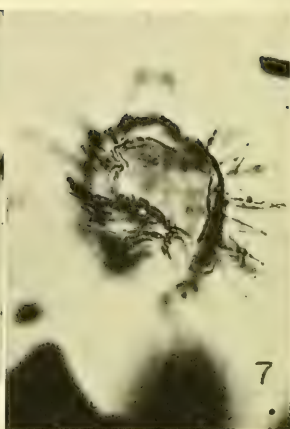
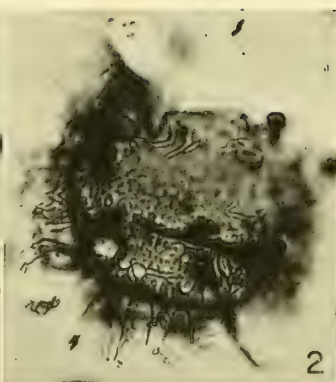
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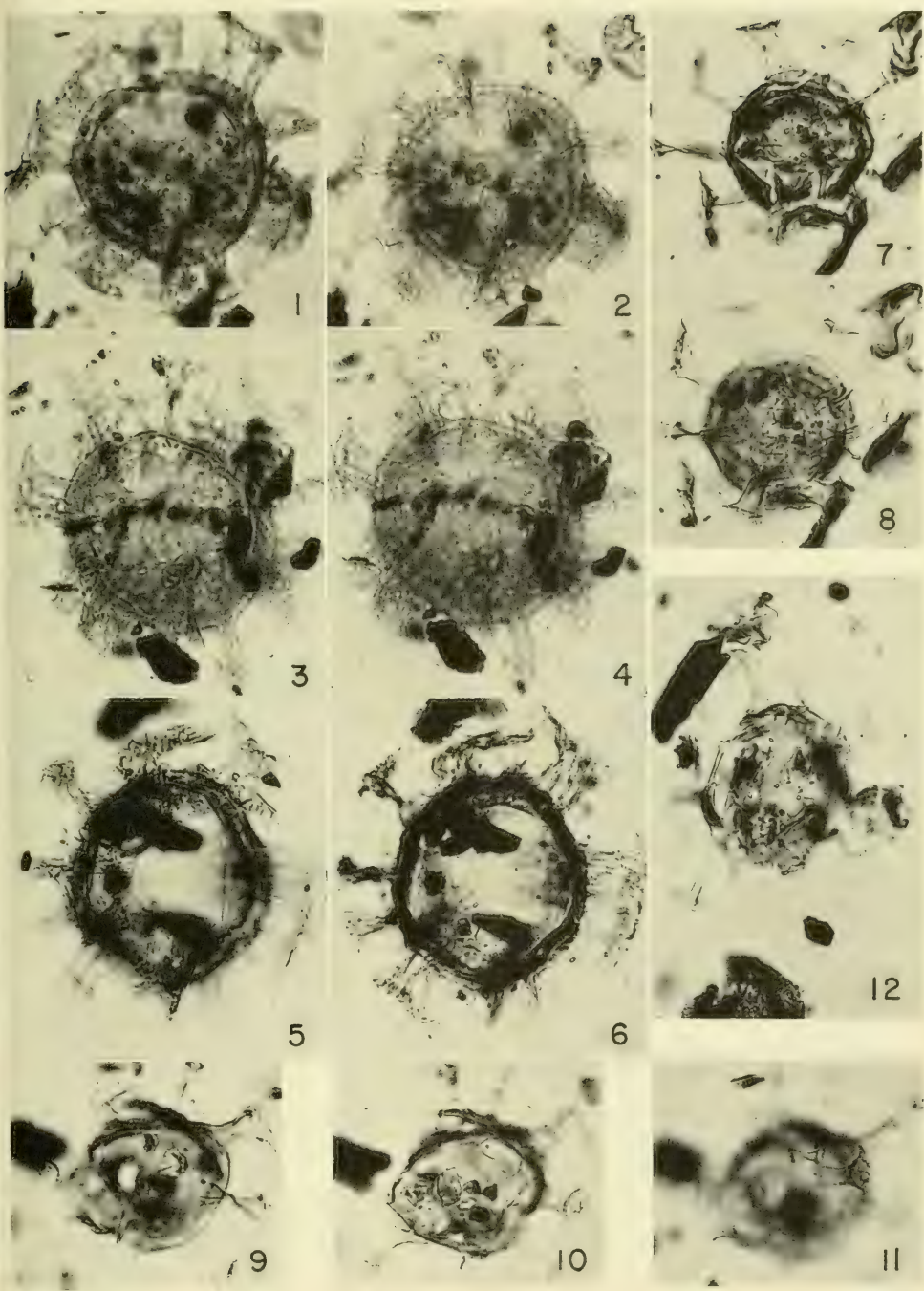
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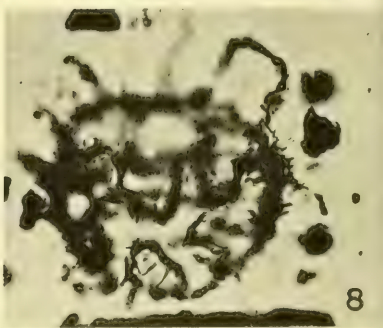
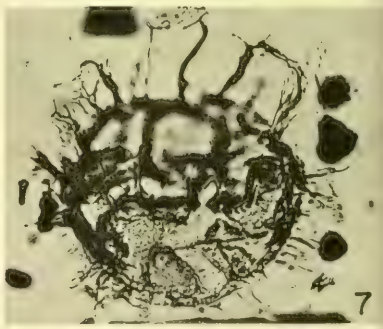
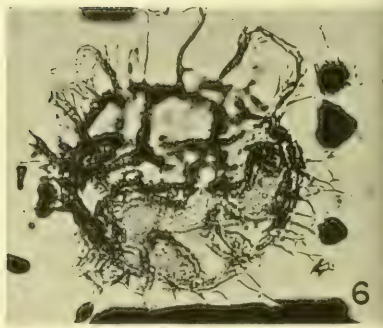
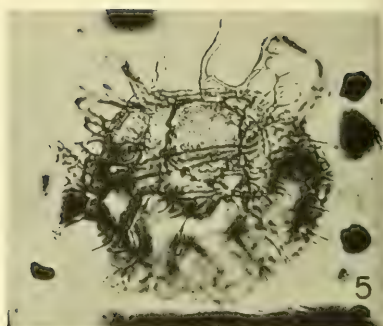
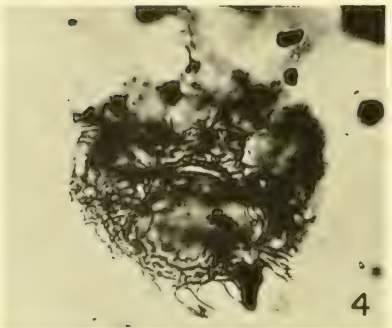
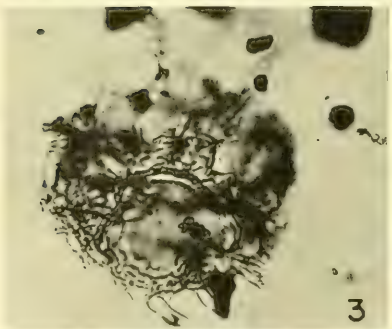
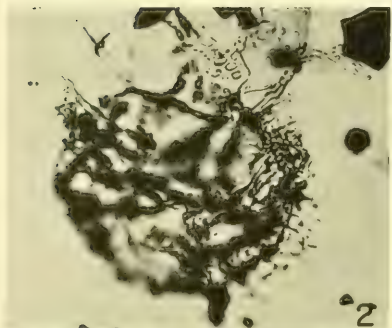
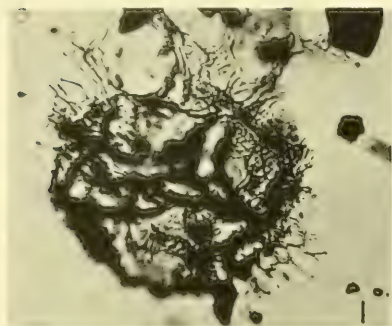
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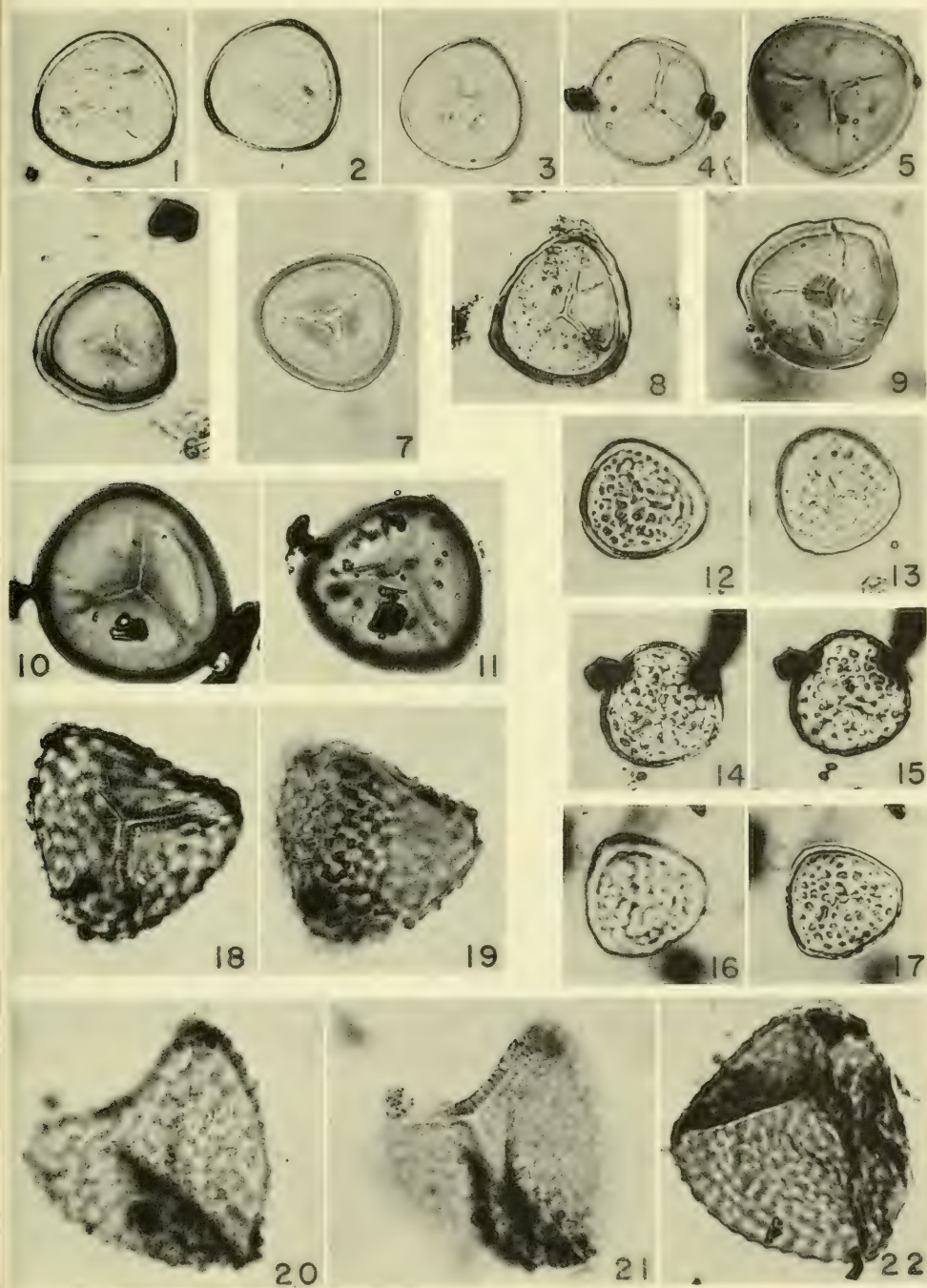
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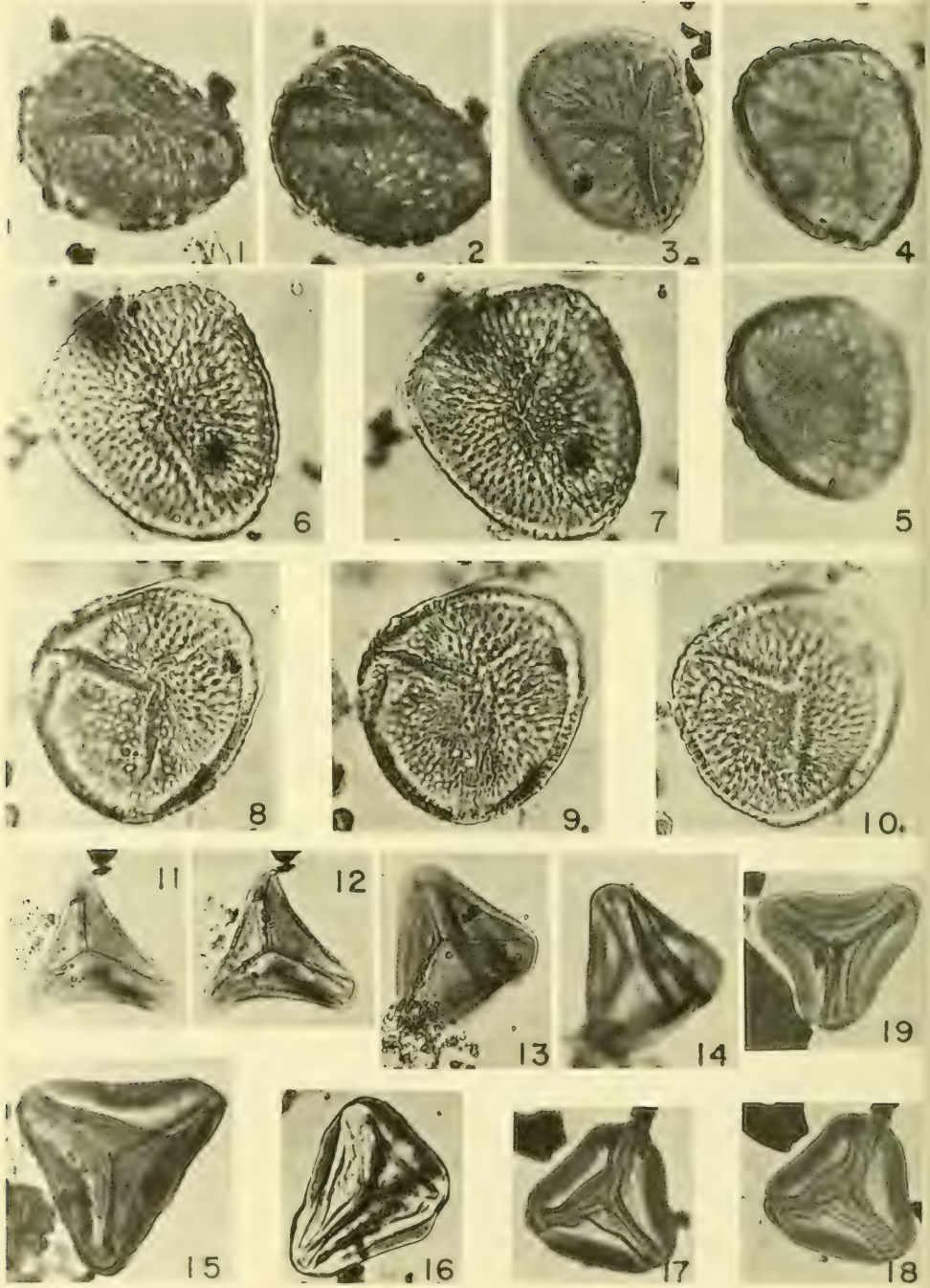
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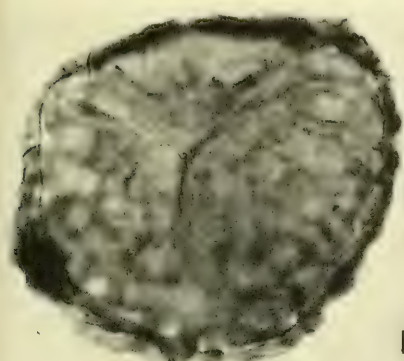
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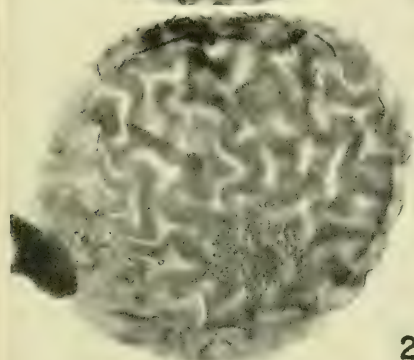
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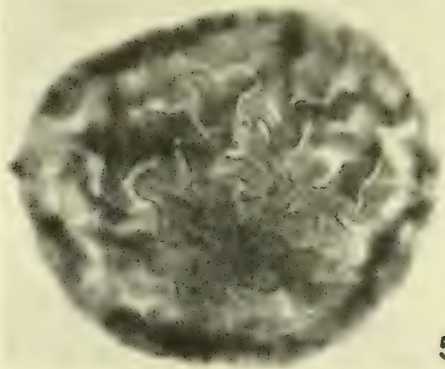
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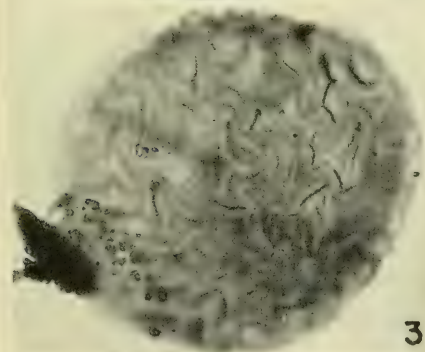
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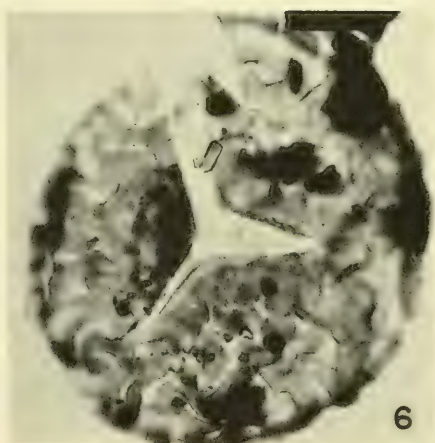
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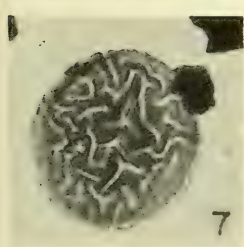
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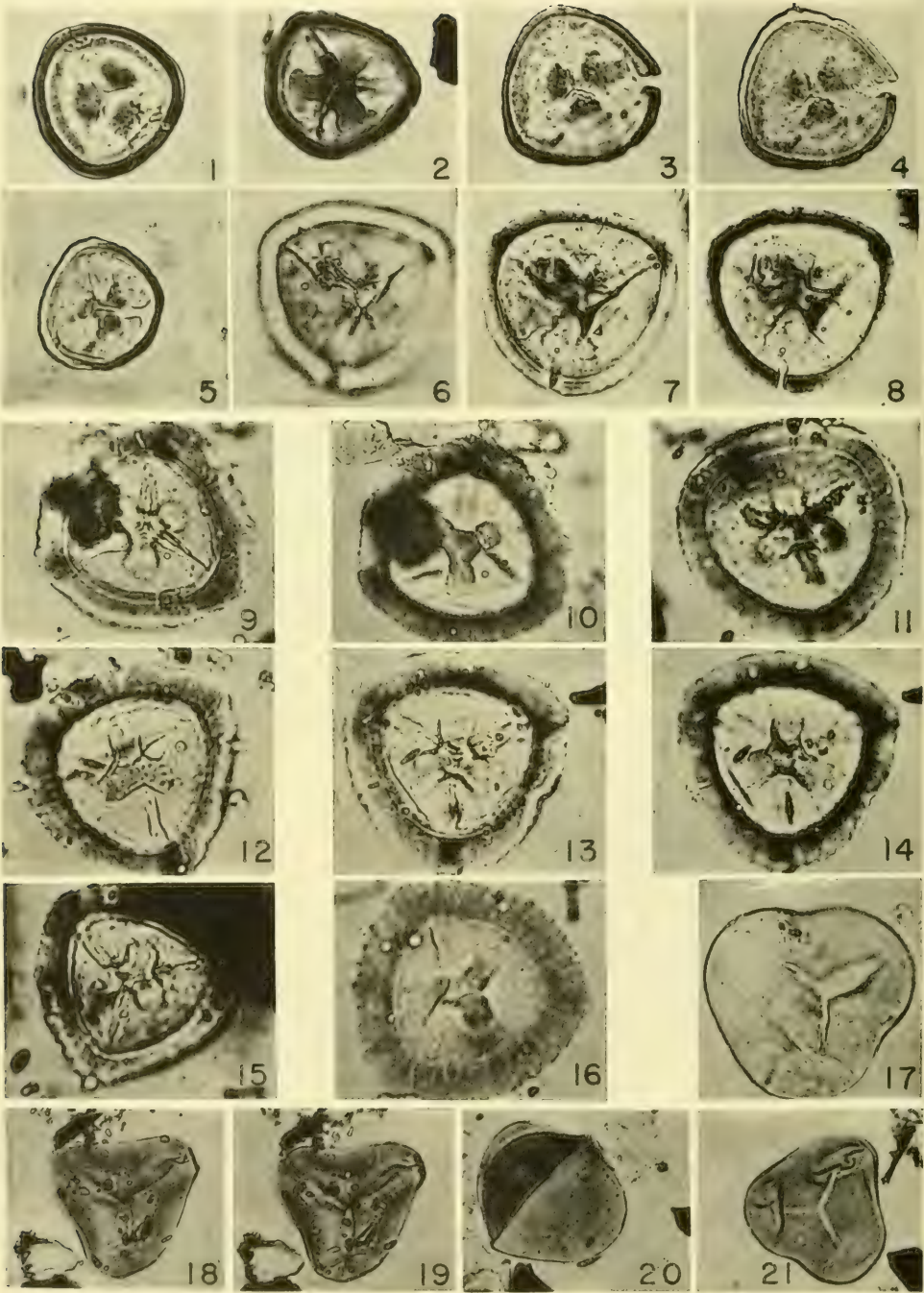
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Explanation of Plate 30

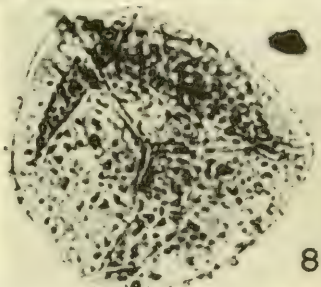
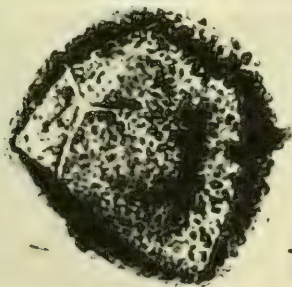
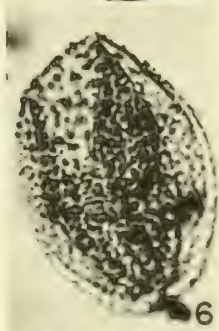
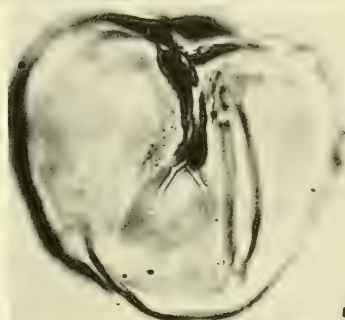
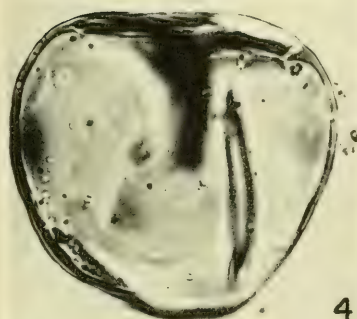
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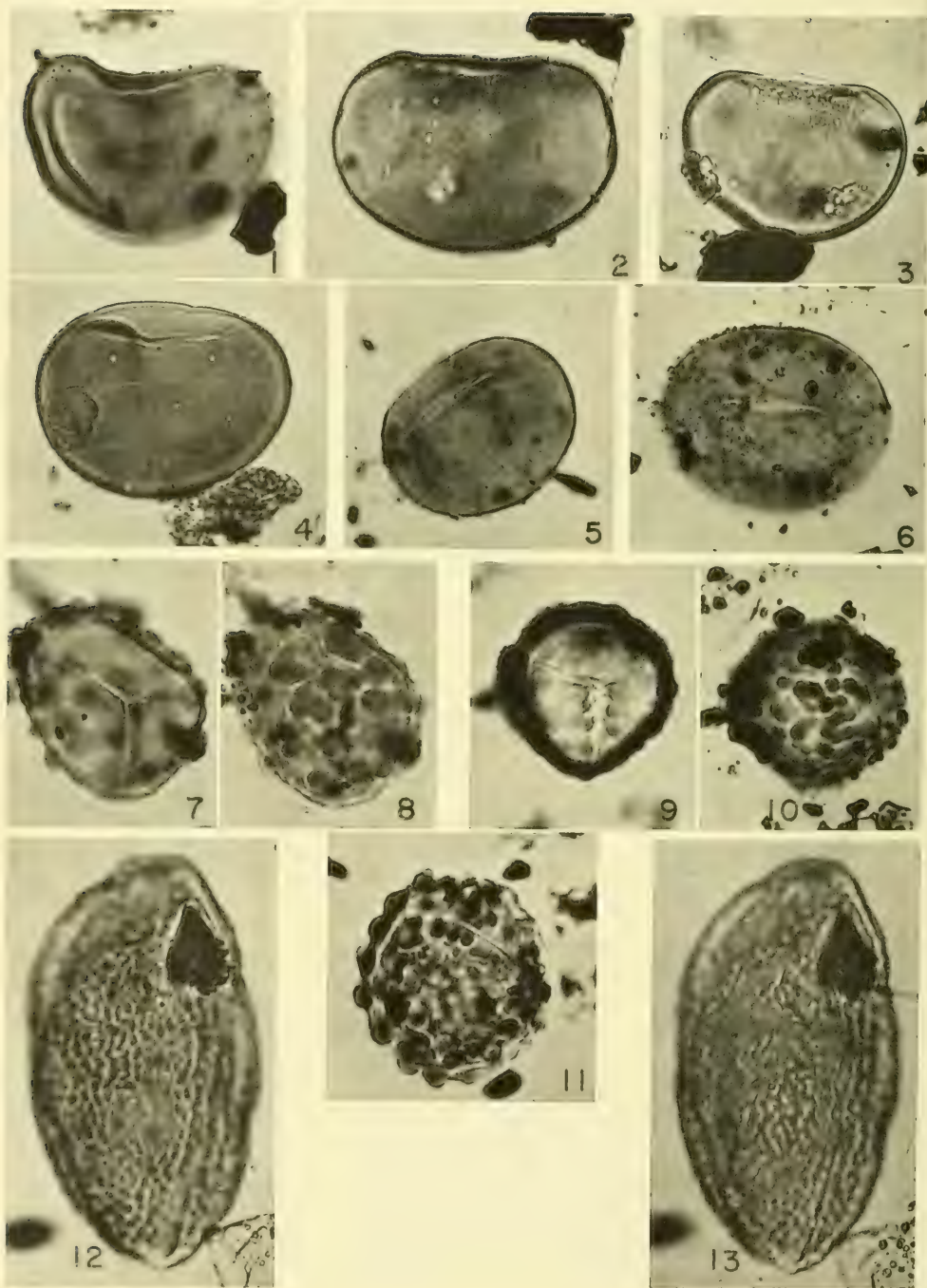
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1-8.	Cingulatisporites dakotaensis , n. sp.	243
	1. Isotype; slide G1-12a-2, 39.4 X 112.6; photo 134/11. 2. Slide G8-2-2, 28.8 X 110.7; photo 124/16-19. 3, 4. Slide G1-12a-1, 36.4 X 93.3; photo 113/5-6. 5. Slide G1-12a-1, 32.2 X 93.5; photo 113/7-8. 6-8. Holotype; slide G1-10-1, 35.5 X 110.7; photo 124/13-15.	
9-16.	Cingulatisporites radiatus , n. sp.	244
	9, 10. Slide G1-8a-2, 40.7 X 107.3; photo 102/16-17. 11. Slide G1-8a-2, 30.1 X 109.3; photo 44/30. 12. Isotype; slide G1-8a-1, 39.2 X 107.2; photo 44/25. 13-14. Holotype; slide G1-8a-2, 29.7 X 96.7; photo 124/22-24. 15. Slide G1-8a-2, 32.0 X 111.3; photo 44/28. 16. Slide 1-8aa, 46.4 X 96.6; photo 44/21.	
17-21.	Cardioangulina diaphana (Wilson and Webster) n. comb.	248
	17. Slide G1-14b-2, 32.8 X 102.9; photo 101/28. 18, 19. Slide S8-1a-1, 40.9 X 93.1; photo 113/9-10. 20. Slide 10-4-3, 25.0 X 111.1; photo 41/34. 21. Slide NS10-4-2, 36.5 X 95.4; photo 42/8.	

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1-5.	Hymenophyllumsporites furcosus , n. sp.	249
	1, 2. Holotype; slide G1-11-1, 21.1 X 112.7; photo 101/1-2. 3. Iso-	
	type; slide S1-8a-6, 38.6 X 101.4; photo 46/35. 4, 5. Slide G1-	
	8a-2, 32.9 X 94.0; photo 102/32-33.	
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	6. Slide 1-11c, 23.6 X 106.3; photo 44/12. 7. Slide 1-18m-1, 40.4	
	X 100.8; photo 42/21. 8. Slide 1-11c, 30.1 X 104.5; photo 44/13.	
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	24.6 X 111.5; photo 101/3. 12. Slide S1-18-9, 32.4 X 103.7;	
	photo 134/9-10.	





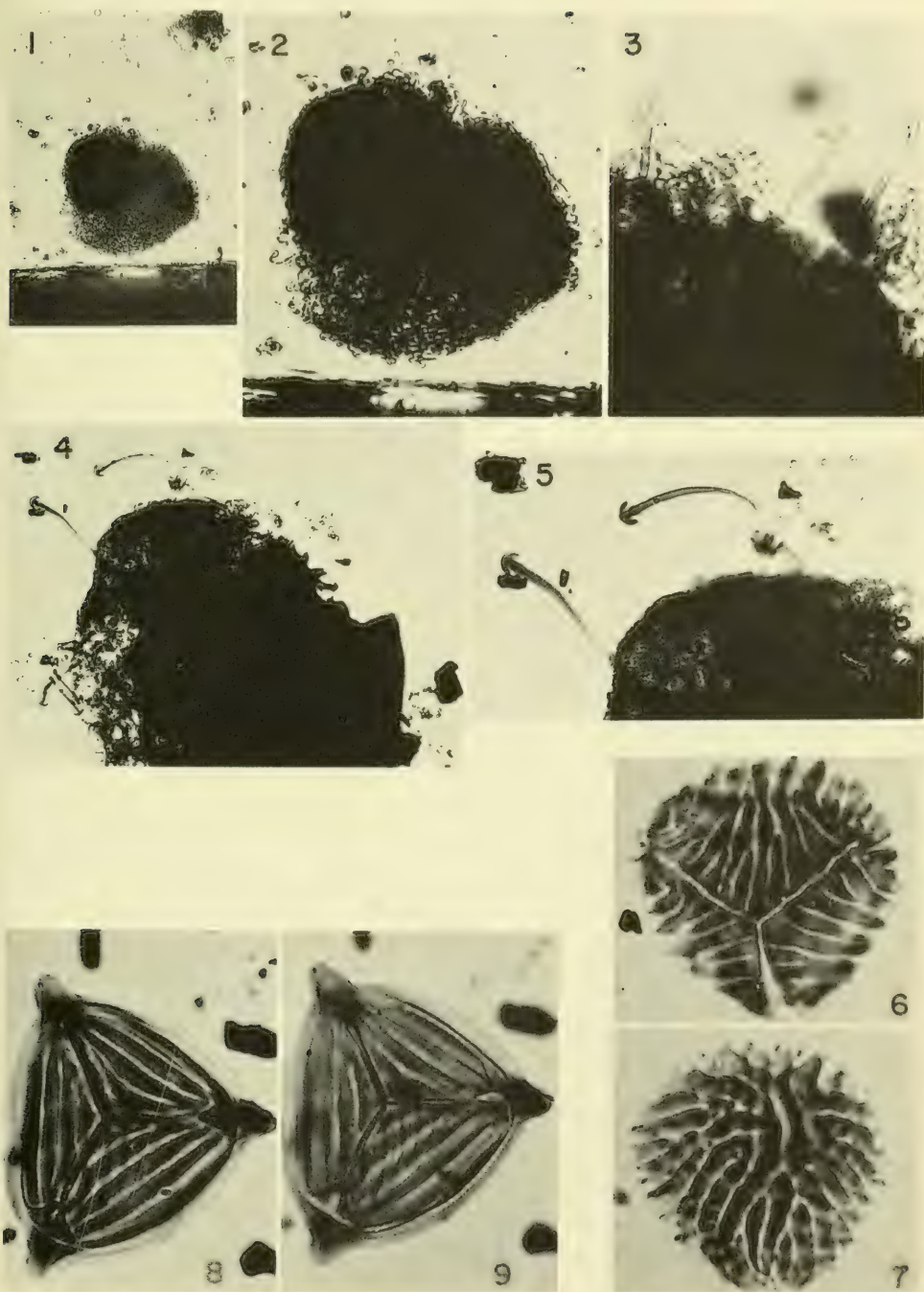
Explanation of Plate 32

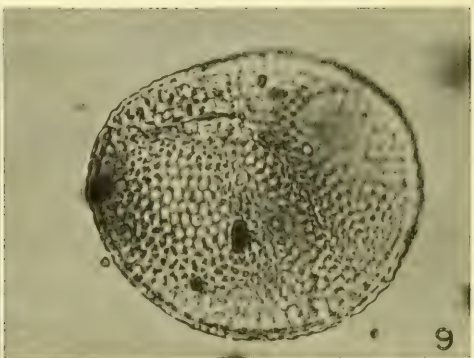
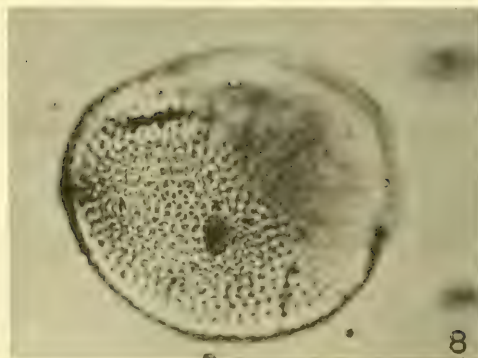
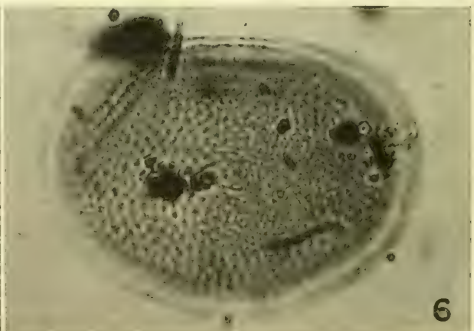
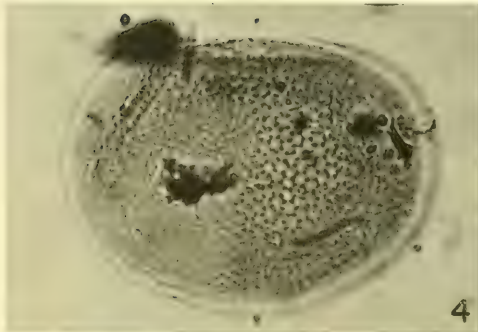
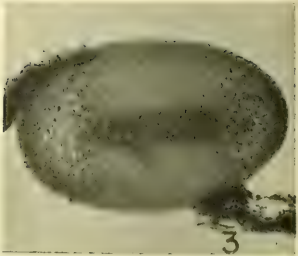
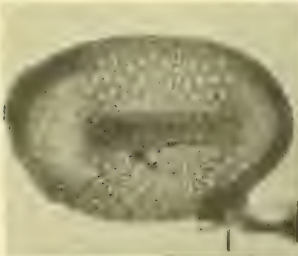
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	4. Slide NS10-4-1, 39.0 X 94.1; photo 42/2. 5. Slide 1-18NS-c, 33.0 X 110.2; photo 38/5. 6. Slide 1-18NS-c, 28.6 X 103.3; photo 38/7.	
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12, 13.	Ovoidites ligneolus Potonie ex Thomson and Pflug.	316
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	1-3. Slide G1-22b-1, 25.6 X 96.4; photo 114/2-4. Fig. 1, 100X; fig. 2, 200X; fig. 3, 700X. 4, 5. Holotype; slide 8-1a-2, 28.0 X 106.4; photo 114/15-16. Fig. 4, 500X; fig. 5, 700X.	
6, 7.	<i>Anemia radiata</i> (Krutzsch), n. comb.	258
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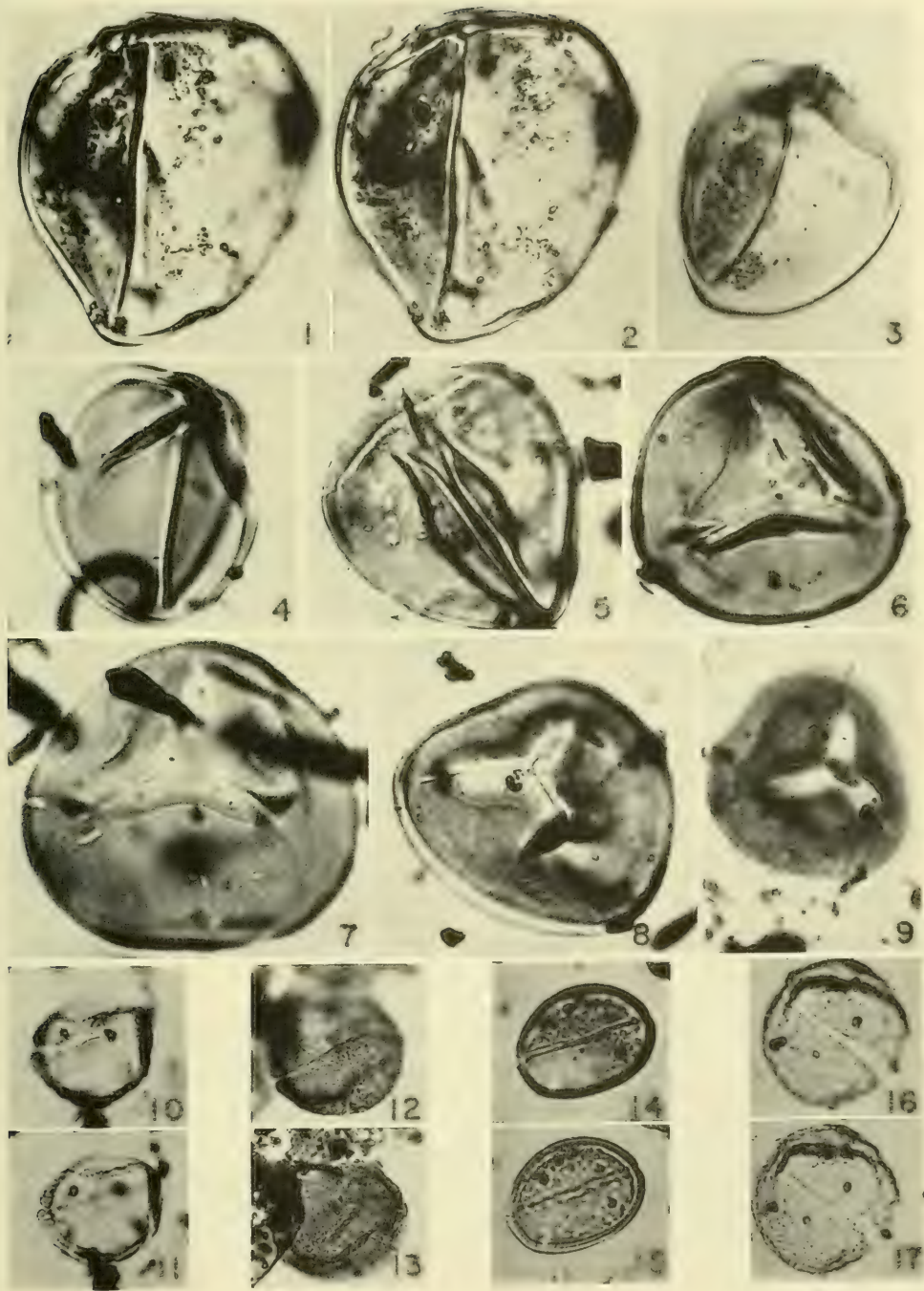
Explanation of Plate 34

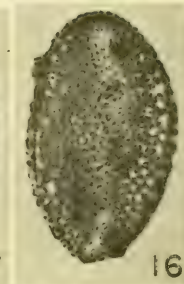
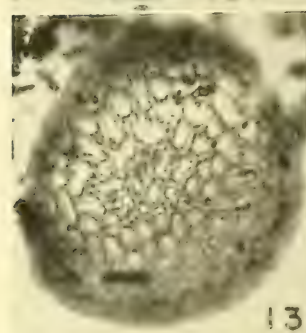
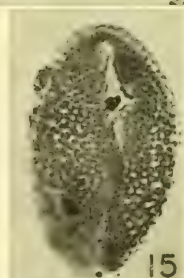
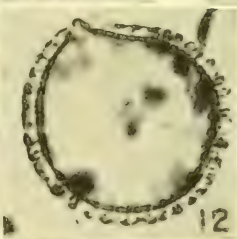
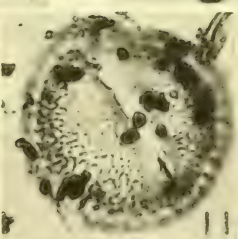
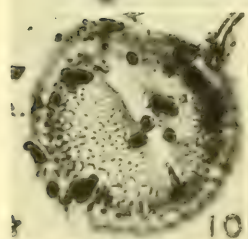
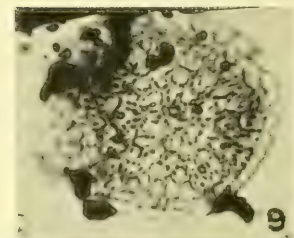
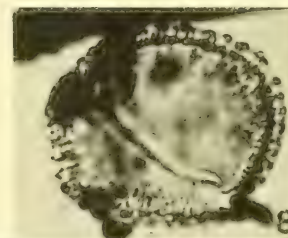
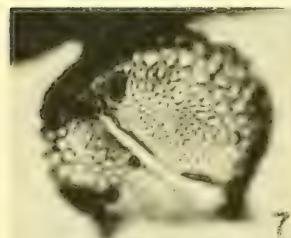
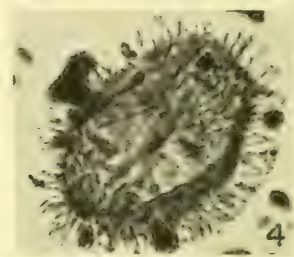
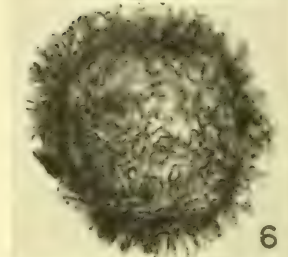
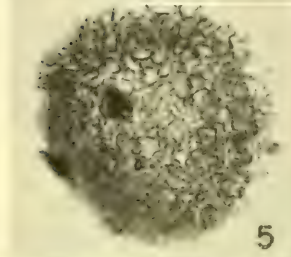
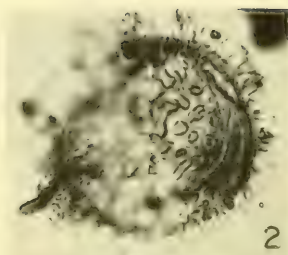
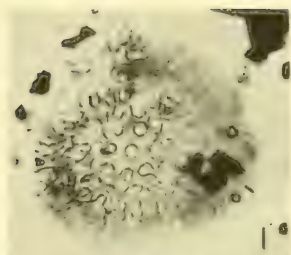
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1-3. Schizaea plectilis , n. sp.	261
Holotype; 400X; slide S8-1a-2, 39.8 X 107.4; photo 116/29-31.	
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1, 2. Slide G1-11-1, 26.8 X 92.0; photo 101/21-22. 3. Slide G1-11-1, 25.7 X 106.7; photo 51/3. 4. Slide 1-11c, 42.4 X 109.0; photo 44/10. 5. Slide G1-8-3, 22.5 X 113.2; photo 44/34.	
6-9. Toroisporis major (Pflug) n. comb.	265
6. Slide 1-22aa, 39.7 X 98.2; photo 44/9. 7. Slide 1-22ac, 24.9 X 102.9; photo 44/7. 8. Slide 1-22aa, 33.2 X 100.8; photo 44/8. 9. Slide 1-18-m-1, 32.5 X 107.3; photo 42/11.	
10-17. Schizosporis scabratus , n. sp.	269
10, 11. Holotype; slide SCB-11-11, 45.5 X 102.2; photo 115/4-5. 12, 13. Slide S8-1a-3, 33.5 X 110.5; photo 113/18-19. 14, 15. Slide SCB-12-1, 25.7 X 101.0; photo 46/18-19. 16, 17. Isotype; slide SCB-12-4, 35.1 X 106.0; photo 46/12-13.	





Explanation of Plate 36

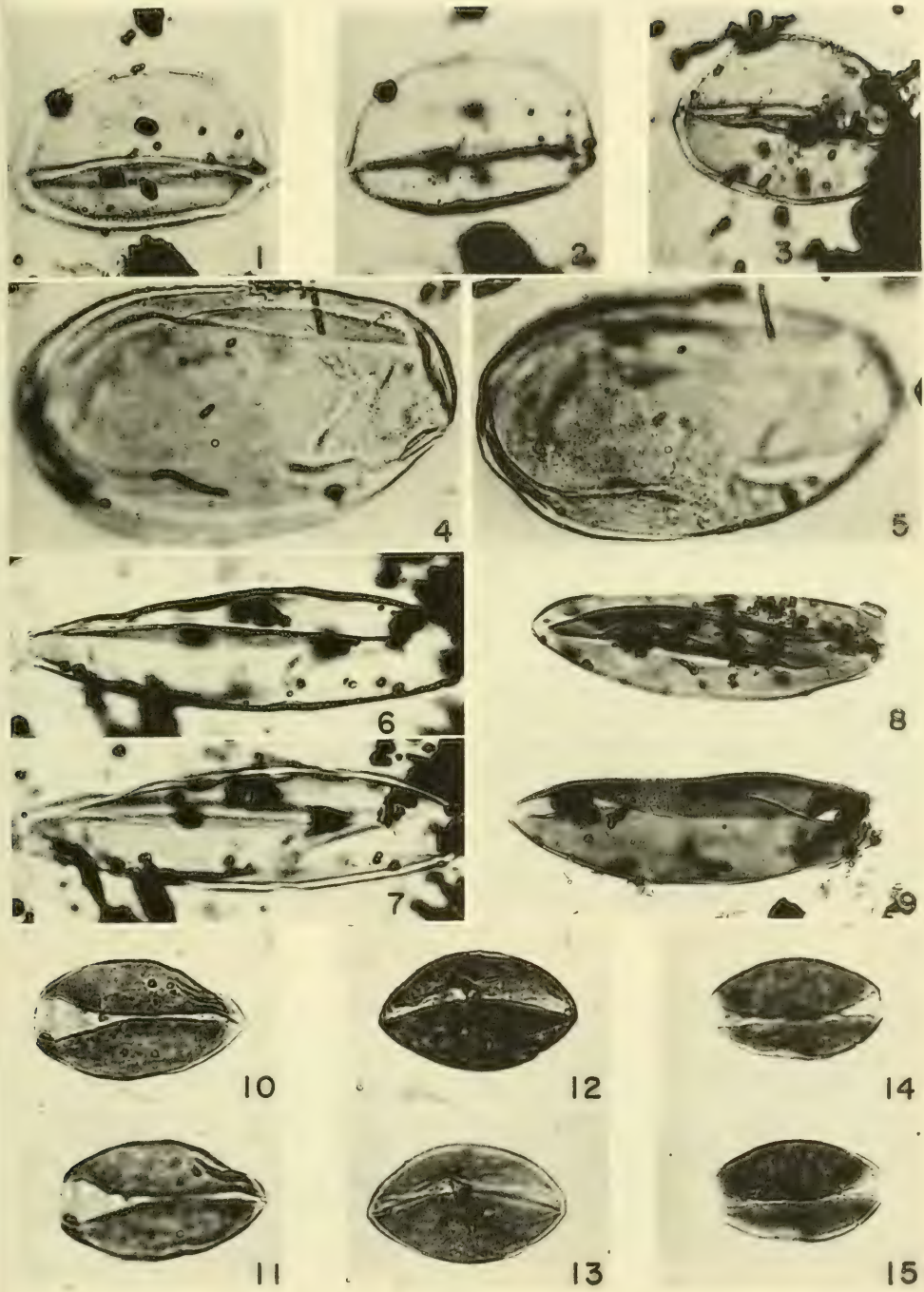
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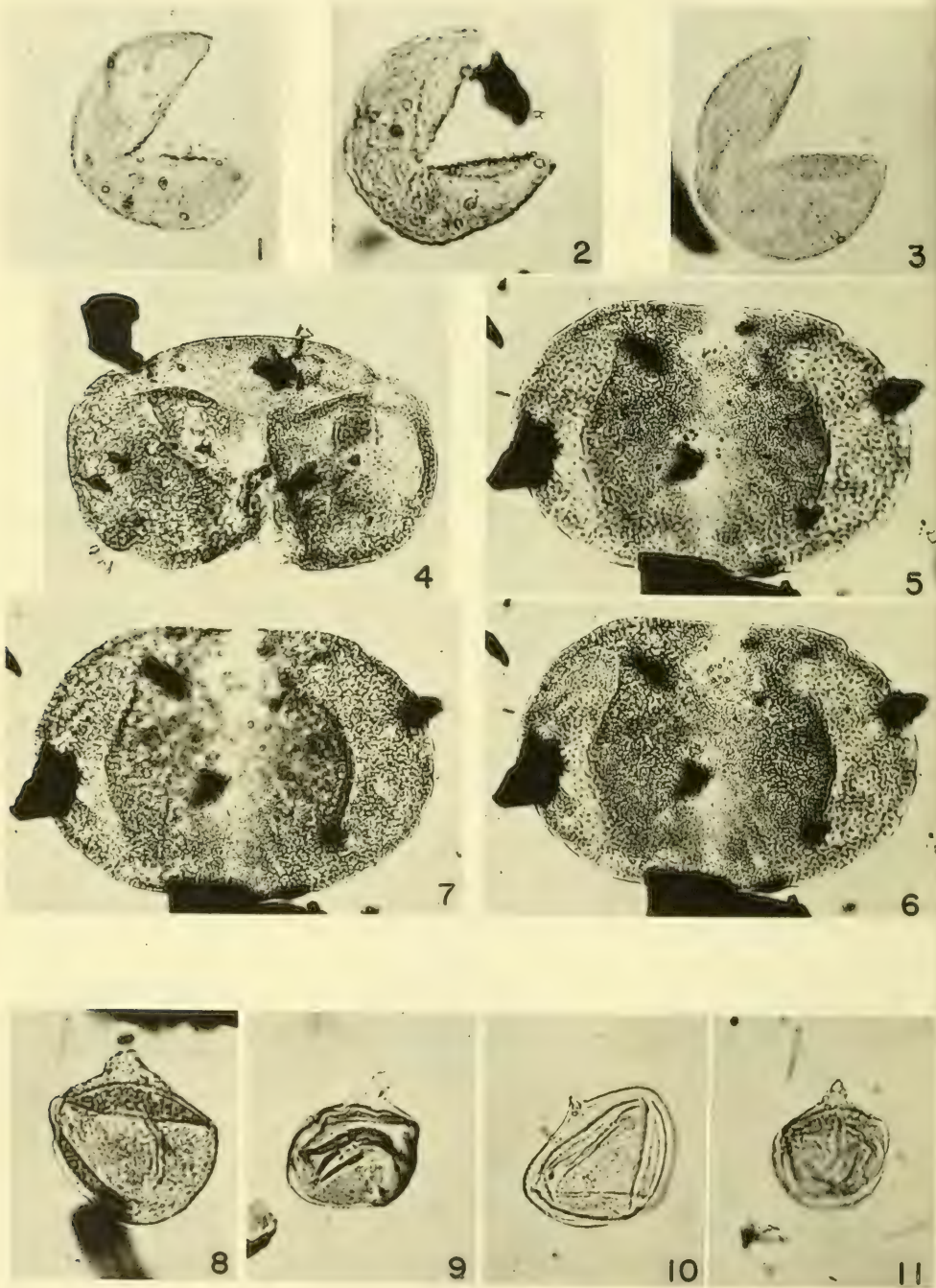
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1-6.	Reticulatasporites cristatus , n. sp.	266
	1, 2. Holotype; slide SCB-11-11, 29.2 X 106.2; photo 53/34-35. 3,	
	4. Slide SCB-11-8, 30.0 X 96.6; photo 40/27-28. 5, 6. Isotype;	
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	Slide SCB-0-8, 37.0 X 115.1; photo 39/22-24. 15-17. Slide CB-	
	11NS-B, 37.5 X 95.1; photo 104/11-14.	

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	6, 7. Holotype; slide SCB-11-8, 37.9 X 111.1; photo 118/4-6. 8.	
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	Slide 18-3-6, 36.7 X 104.7; photo 118/14-16.	





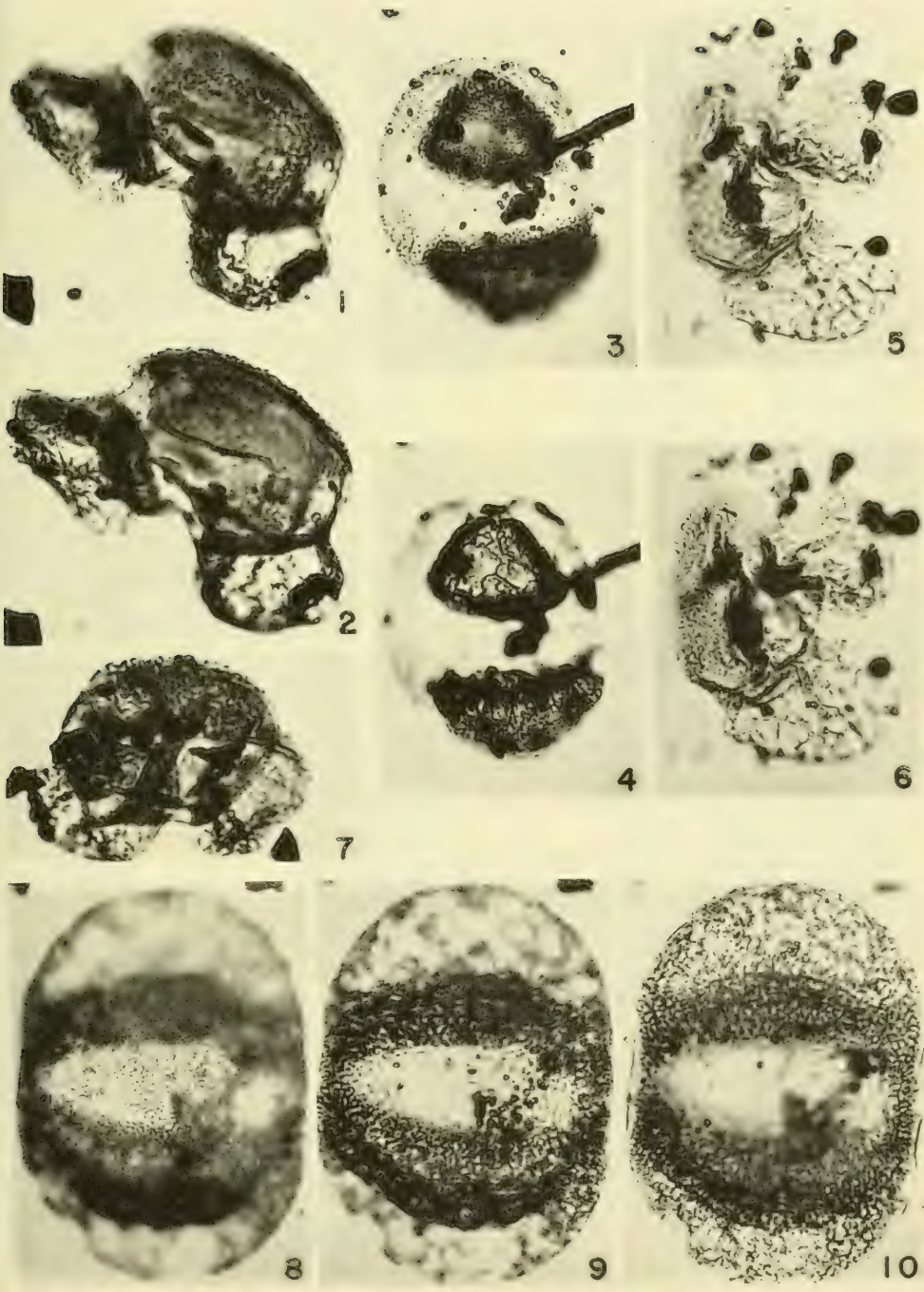
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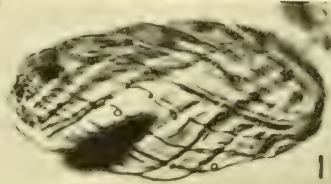
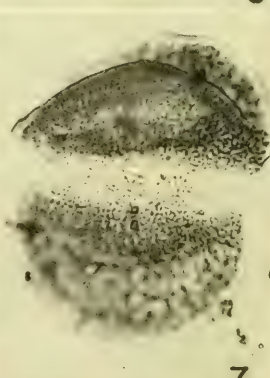
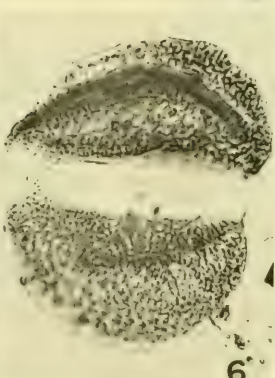
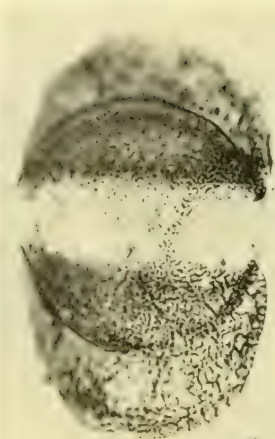
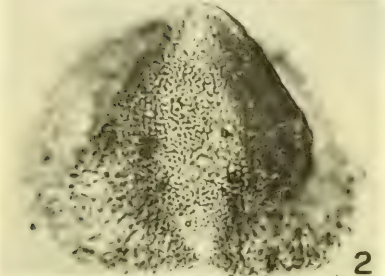
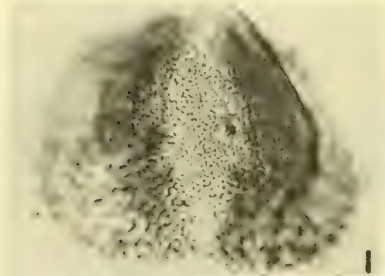
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1-3. Thuja ? hiatus (Potonie), n. comb.	273
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8-10.	Pinus semicircularis , n. sp.	277
	Isotype; slide 18-3-1, 32.3 X 108.8; photo 118/22-24.	





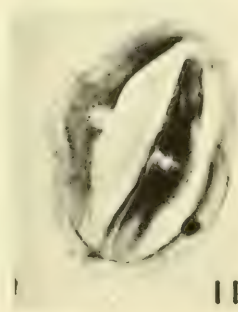
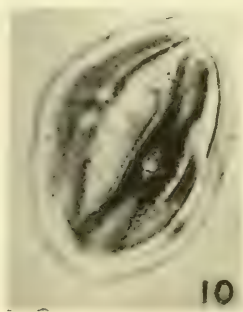
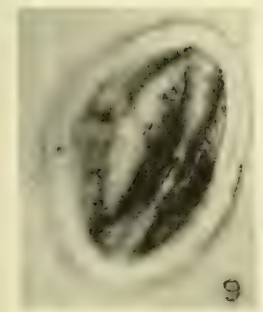
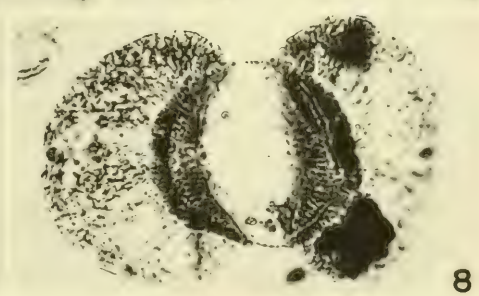
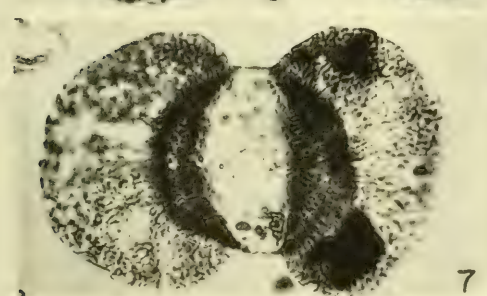
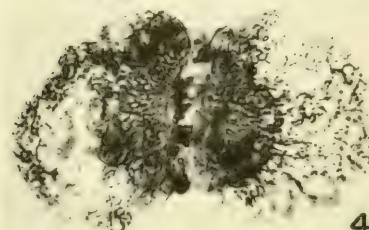
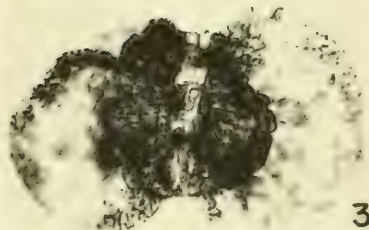
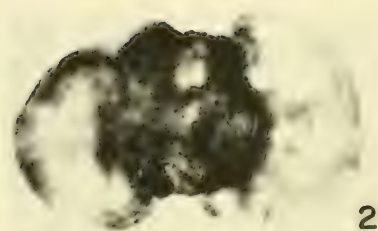
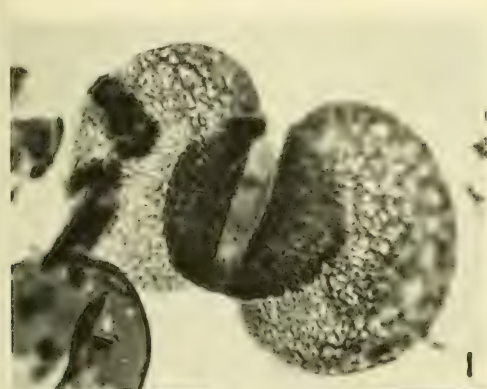
Explanation of Plate 40

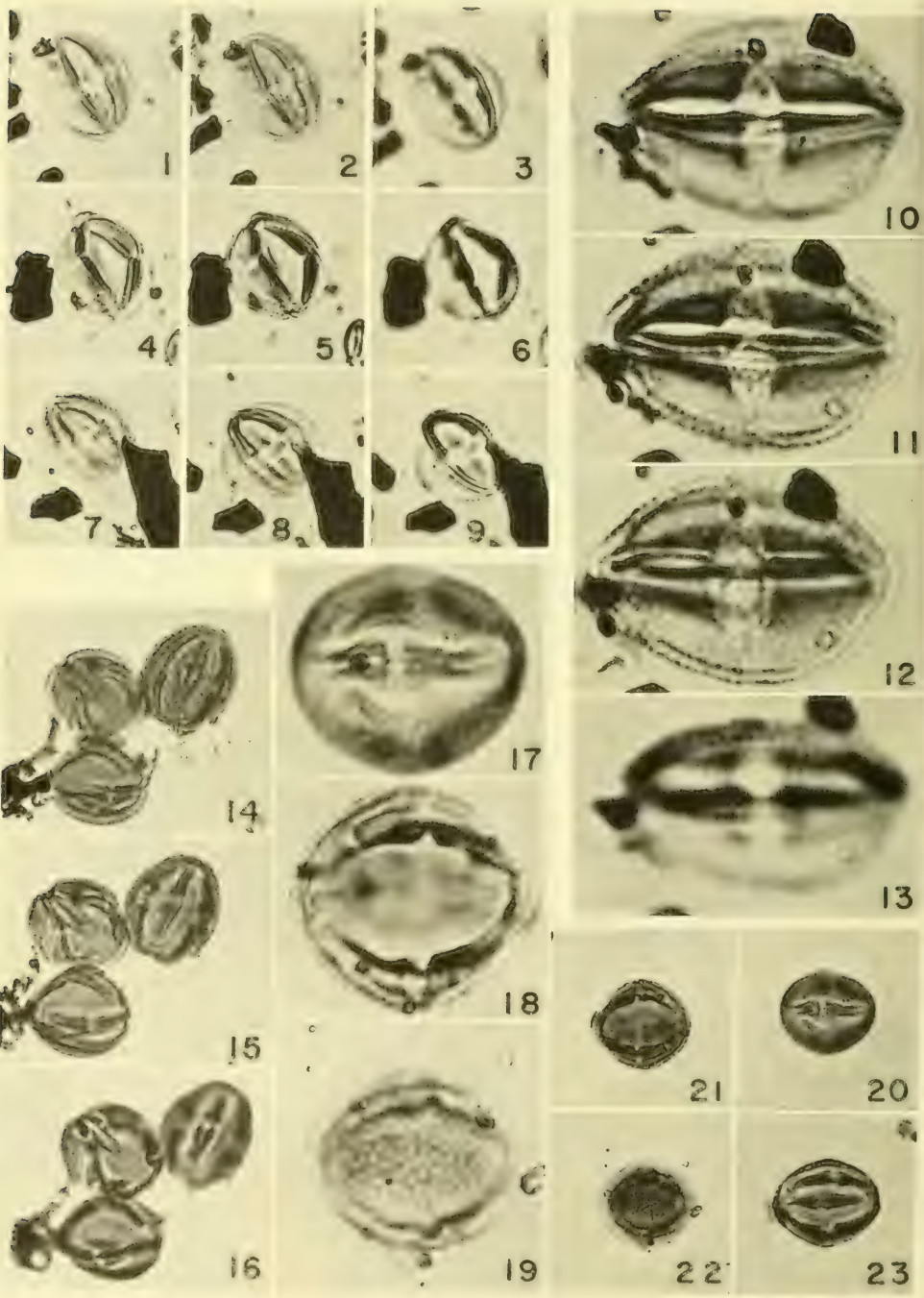
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	1-3. Holotype; 800X; slide 18-3-2, 37.2 X 100.2; photo 119/21-23.	
	4, 5. Slide 18-3-2, 27.3 X 111.5; photo 119/11-12; 800X. 6, 7.	
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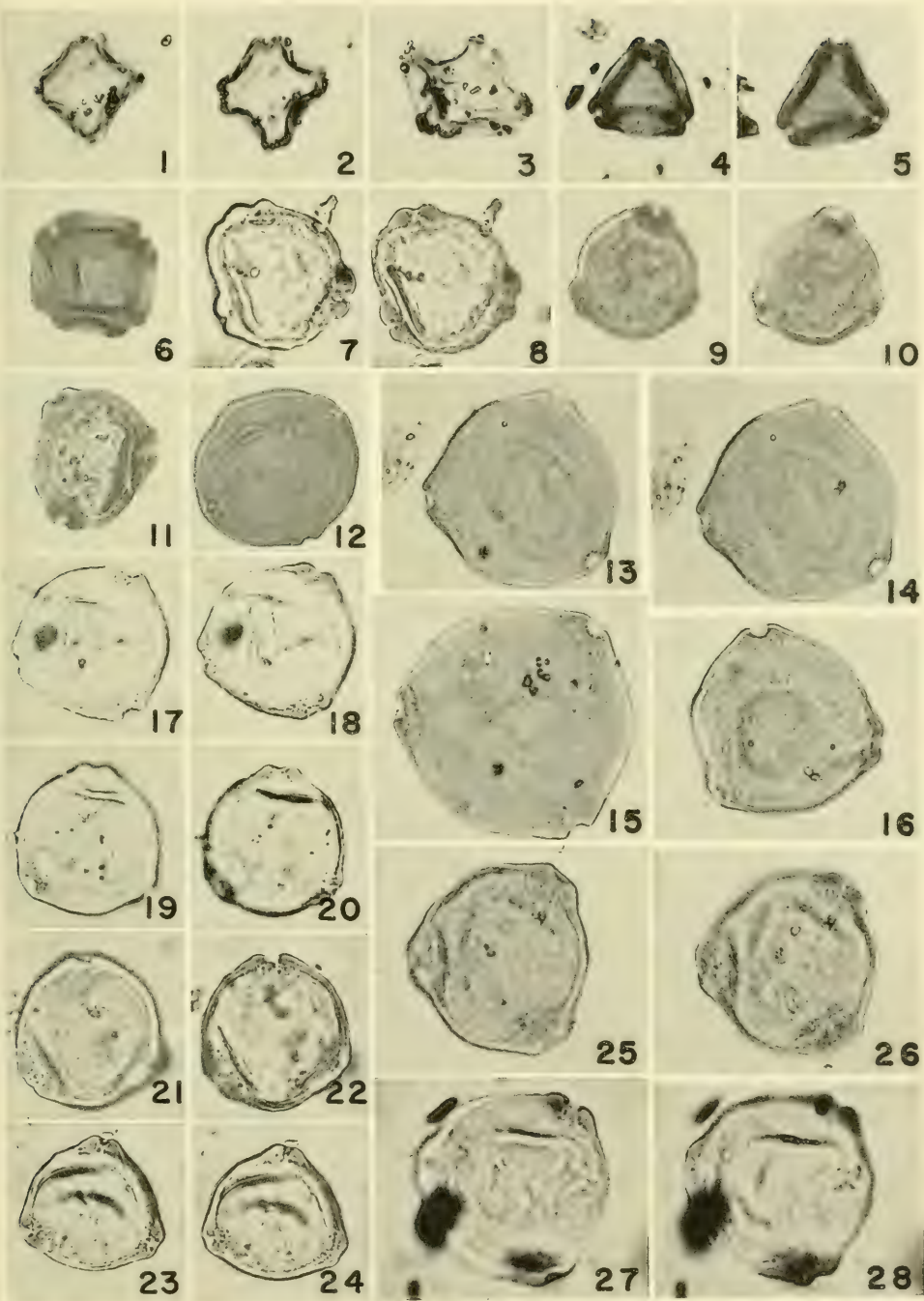


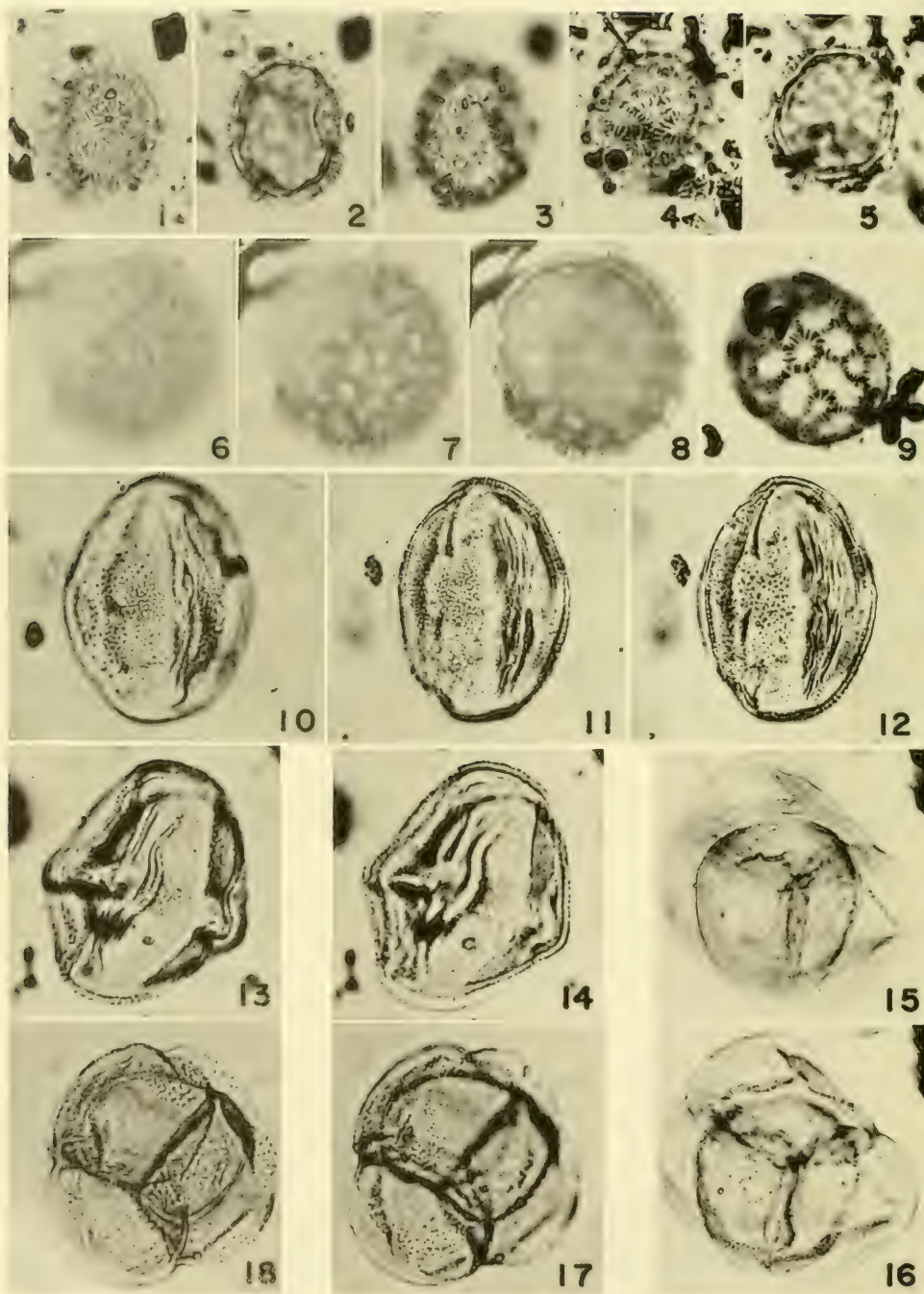
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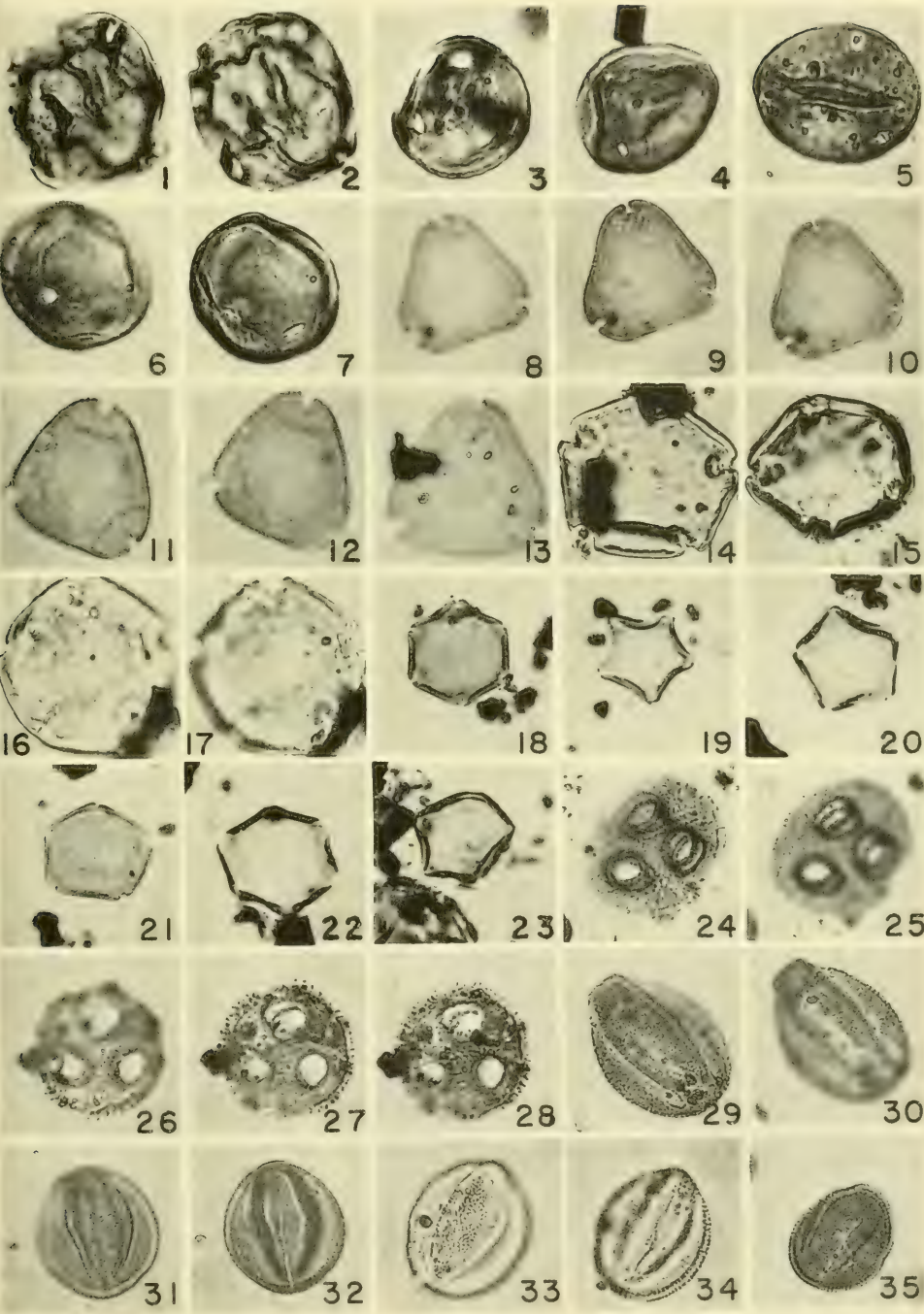


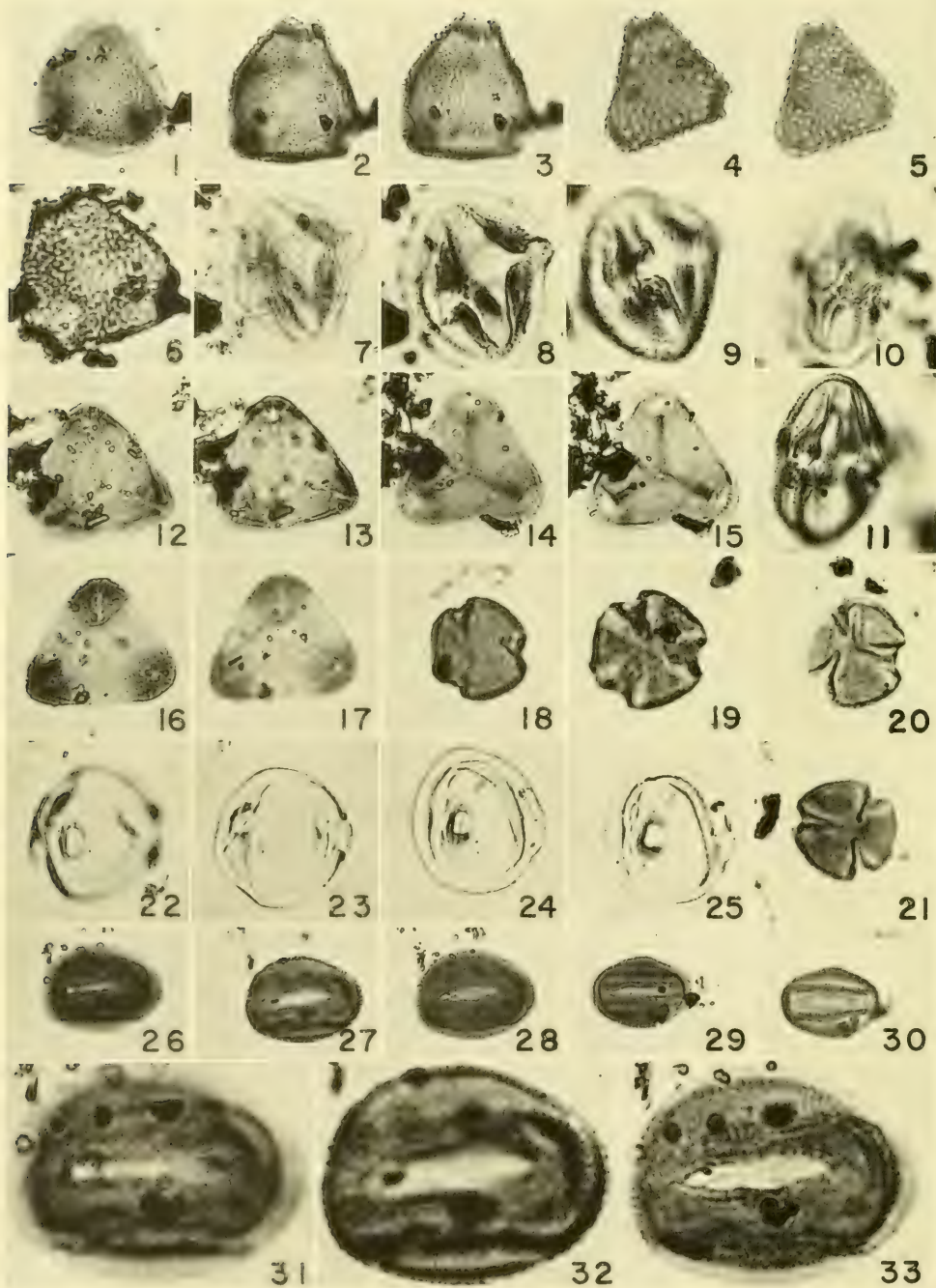
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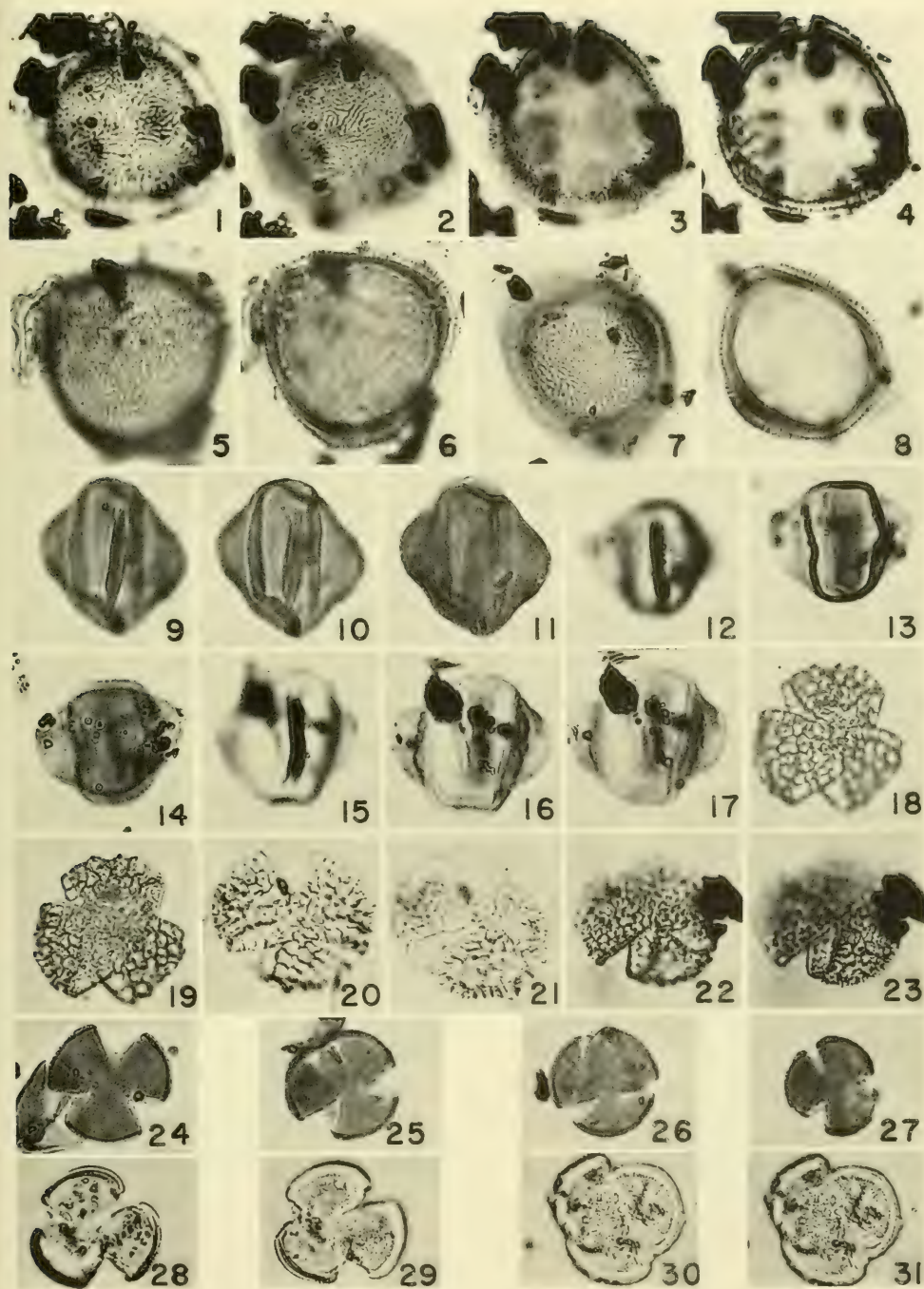
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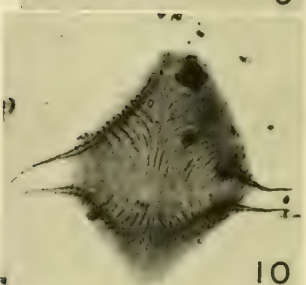
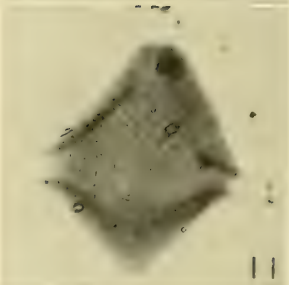
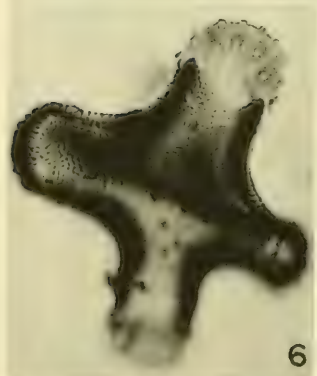
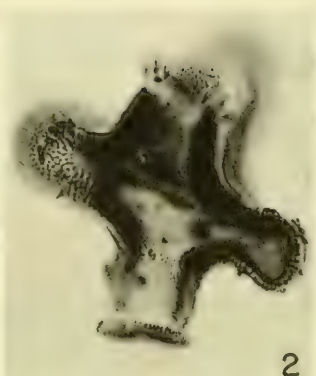
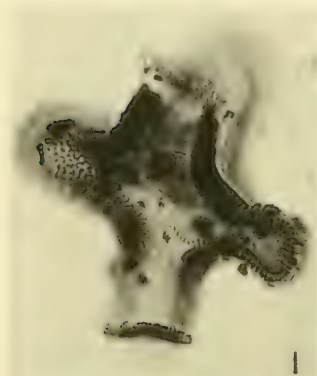
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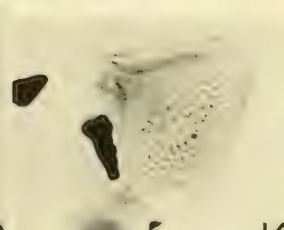
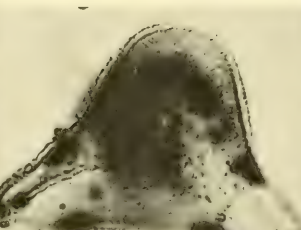
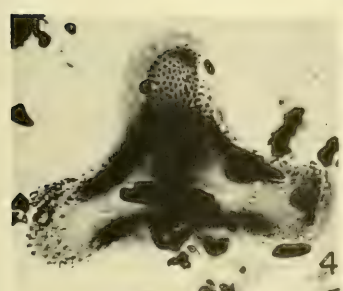
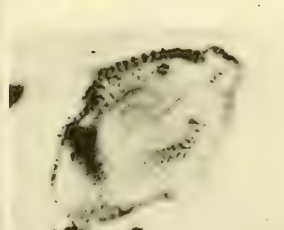
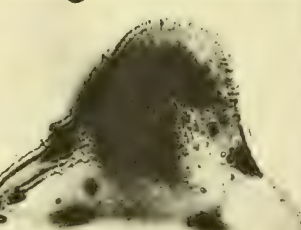
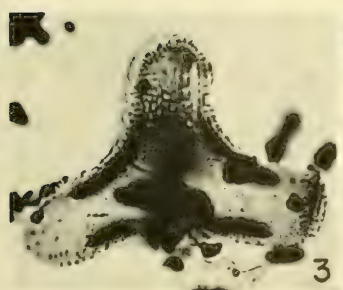
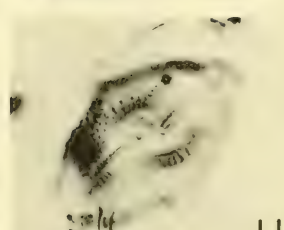
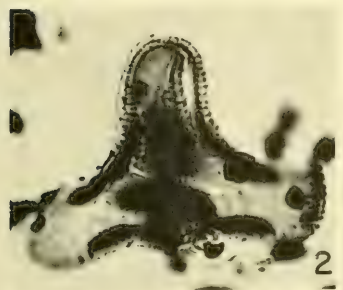
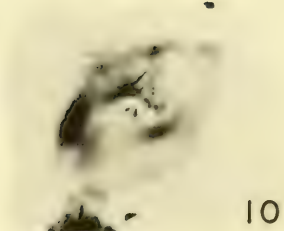
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MIOCENE MOLLUSCA FROM THE
PARAGUANA PENINSULA, VENEZUELA

By

PETER JUNG

Paleontological Research Institution
Ithaca, New York, U.S.A.

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MIOCENE MOLLUSCA FROM THE PARAGUANA PENINSULA, VENEZUELA

PETER JUNG

ABSTRACT

A molluscan fauna of 146 species (2 scaphopods, 49 pelecypods, 95 gastropods) with a remarkable degree of endemism is described, compared, and illustrated. Twenty-four species are described as new. The whole fauna derives from a single horizon of the Miocene of Central Paraguaná, Venezuela, and represents a tropical shallow water assemblage. Comparison with assemblages from the Gatún formation of the Panamá Canal Zone, the Cercado and Gurabo formations of Dominican Republic and the occurrence of *Aturia curvilineata* Miller and Thompson suggest an upper middle Miocene age of the Paraguaná fauna. It is thought to be slightly older than the Bowden fauna of Jamaica.

RESUMEN

Objeto del trabajo es la descripción, comparación y ilustración de 146 especies de moluscos (2 Scafopodos, 49 Pelecypodos, 95 Gasteropodos): éstas incluyen un número notable de formas endémicas. Veinticuatro especies son descritas por primera vez. Toda esta fauna proviene de una sola zona del Miocene de Paraguaná, Venezuela, y representa un aspecto litoral tropical. Una comparación con las faunas de la formación Gatún de la Zona del Canal de Panamá y de las formaciones Cercado y Gurabo de Santo Domingo, así como la presencia de *Aturia curvilineata* Miller y Thompson hacen suponer una edad del Mioceno Medio Superior para la fauna de Paraguaná. Se estima que ésta es poco más antigua que la fauna de Bowden en Jamaica.

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But above all I am happy to thank here Dr. H. G. Kugler. His initiative, his enthusiasm, his patience, and, last not least, his financial support are the background of this paper. He has made possible the compilation of a catalogue of scaphopod, pelecypod,

and gastropod species, which is a working instrument representing a *conditio sine qua non*.

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INTRODUCTION

In the field of Neogene molluscan paleontology covering the Caribbean province (its present extension is shown by Warmke and Abbott 1961, 1962, p. 319) only a few faunal inventories of single horizons have been drawn up. By far the largest report of this kind has been published by Woodring (1925, 1928) for the famous fauna from Bowden, Jamaica. In 1934 Rutsch described the gastropods of the Punta Gavilán formation, northern Venezuela, and in 1942 he summarized all the previous knowledge of and gave additional information on the rich fauna from Springvale, Trinidad. Comprehensive monographs embracing larger time spaces have been written (in chronological order) by Dall, 1890-1903 (chiefly Florida), Maury 1917 (Dominican Republic), Olsson,

1922 (Costa Rica), Maury, 1925 (Trinidad), Olsson 1932 (Perú), Olsson and Harbison, 1953 (Florida), Woodring, 1957, 1959, 1964 (Panamá), and Weisbord, 1962 (Cabo Blanco, northern Venezuela).

It is the purpose of the present paper to describe and illustrate a stratigraphically fixed fauna. The more the faunas of such localities are known, the better are the possibilities for their correlation and determination of their relative age.

Karsten (1851, p. 467) was the first to record Tertiary fossils from Central Paraguaná. Apparently he did not collect any specimens nor describe such. He wrote:

. . . Die übrigen mit Mergeln und Sandsteinen geschichteten Kalke der Ebene oft in kalkhaltigen Sandstein übergehend und gegen Süden (den Berg von St. Ana) unter geringem Winkel gehoben, sind zum Theil sehr reich an tertiären Versteinerungen . . .

The first descriptions of fossils from Central Paraguaná are contained in the publications by Hodson (1926), Hodson, Hodson, and Harris (1927), and Hodson and Hodson (1931a, 1931b). In 1931 C. Wiedenmayer made an extensive collection in Paraguaná which forms the basis of this report. Additional material was obtained from Cia. Shell de Venezuela. It was collected by O. Renz in 1948. The material collected by Wiedenmayer is labeled N.V.P. Blue No. 3892, which means the blue (= locality) number of the former North Venezuelan Petroleum Company. The locality numbers of the Renz collection are preceded by the letters Re.

All the material mentioned, described, and figured in this report is deposited at the Natural History Museum, Basel, Switzerland. Duplicate sets and casts of several holotypes have been sent to the British Museum (Natural History), the Paleontological Research Institution, Ithaca, New York, and the U.S. National Museum, Washington, D.C.

METHODS

In systematic work one should be governed by one major prerequisite namely: a species concept. However, it is not the intention of the writer to offer an opinion on a subject, which by its nature demands a long experience. A study of literature indicates

that there is one basic difficulty in obtaining a clear species concept: the contrast between the population and the typological concepts of species.

It is claimed that the basic principle for establishment of a species concept should be the study of populations. There does not seem to exist agreement as to the definition and applicability of the term "population." Newell (1956) did not state *expressis verbis* that a population consists of only one generation. Young (1960, p. 351) pointed out, however, that,

if a population consists of only one generation then genetic drift and gene replacement are impossible in a population and only possible in a succession of interbreeding populations, each generation consisting of the offspring of the preceding population. On the other hand, if a population is a geographically variable unit that consists of many related successive generations in time, it is a basic unit which can be discussed and in which gene replacement and drift can proceed. But temporal variation has been added, and such a population can no longer be expected to maintain the same statistical parameters as the single generation population . . .

Sylvester-Bradley's (1951, p. 89) formulation of this problem is as follows:

The term *chronodeme* is here proposed to distinguish populations separated by time, whether or no morphological change is apparent. No limit of time interval is specified in this definition, so that theoretically a living population passes from one chronodeme to another with the passage of minutes just as it does with the passage of millions of years. In practice, however, it will be convenient for the palaeontologist to include within the one chronodeme all fossils of the species found within a single "bed," even though it is unlikely (or impossible) that all were alive at one and the same time. The arbitrary limits of the chronodeme will therefore depend on the limits ascribed to the "bed" and may be varied to suit the circumstances.

The applicability of the term "population" in paleontology has been considered as doubtful, and "supply" has been used as a substitute term. Young (1960, p. 356) wrote:

A species is an interpretation of a sample of a population or populations, or samples of populations; more simply and accurately a sample from a supply.

The typological concept of species has suffered critical attacks. Young (1960, p. 356) writes:

I do object to the unrealistic attempts to make the species objective; this is exactly what the typologists have tried to do, and the paleozoologists should object most vociferously.

This is a rather extreme formulation, for even typologists know that species cannot be objective. The typological system does not try to make species objective but represents an appropriate means to avoid extreme subjectivism. Or, translated into practice: in any case it will be advantageous to examine type specimens, in order to decrease the number of possible misidentifications. Reports, in which this has been done, are much more trustworthy.

To have a species concept further includes the knowledge of the variability of a given species. To know the range of variation, however, offers three eminent difficulties:

First: the distinction of horizontal and vertical variability (the New Palaeontology of Sylvester-Bradley 1956). The material of this thesis originates from a stratigraphic unit that has a maximum thickness of about 75 m. thus representing a time interval with a succession of many generations. In a large sense one species of this material may represent a chronodeme according to Sylvester-Bradley's "practical" definition, although the possibility of some morphological changes due to vertical distance cannot be excluded.

Second: the disproportion of the surface of the outcrop of a fossil locality to the volume of sediment (inaccessible plus eroded), in which these fossils occur, plus the subjective manner of collecting, results in an infinitesimal and thus unrepresentative selection of specimens to be studied. In addition the extremes of the variability are not likely to make part of a single collection.

Third: a fossil assemblage never represents a biocenose nor a necrocenose. Sorting according to size by wave-action, redeposition by currents or similar forces are probable, especially for a shallow-water fauna.

The above quotations and considerations lead to the conviction that the morphological limits of a "species" should not be restricted too much. Wherever the abundance of the material has allowed, a few remarks on the variability have been added. The holotype and other type specimens have been examined, where this was possible. Thus an attitude between extreme typological and extreme population concepts of species seems to be possible.

The *termini technici* used in this paper are generally in accordance with those defined by Olsson (1961, pp. 49-51) for pelecyc-

pods and those given in the *Treatise on Invertebrate Paleontology, Part I, Mollusca I* (1960, pp. 129-134) for gastropods. The counting of volutions of gastropod protoconchs is defined under *Ficus carbasea* (Guppy).

The numbers that pertain to each specimen in the explanations of the plates, refer to the catalogue of the Natural History Museum, Basel, if not otherwise specified. The letter H includes Gastropoda, and G. Pelecypoda and Scaphopoda.



Text fig. 1. Index map showing the geographic location of the Paraguaná Peninsula.

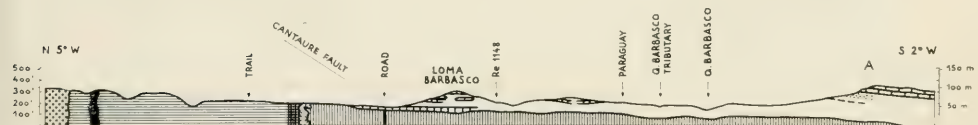
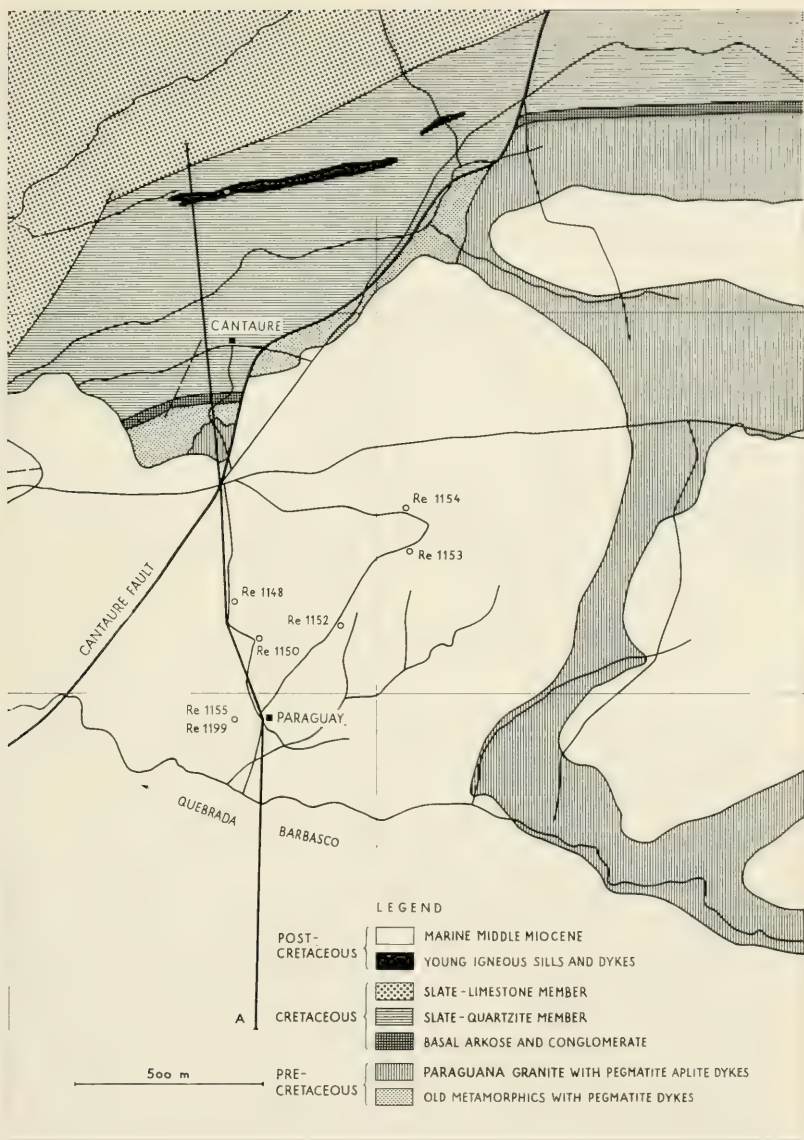
LOCALITY DATA

Wiedenmayers' original locality label is as follows:

About 500 m south of House "Cantaure" near Mesa de Cocodite, west of Pueblo Nuevo, central part of Paraguaná Peninsula, District Falcón, State of Falcón, North Venezuela.

Hodson's locality No. 2207 is described by Hodson and Hodson (1931a, p. 6) as follows:

Cantaura, Cocodito (or Cocodite) area, Paraguaná Peninsula, District of Falcón, Falcón.



Text fig. 2. Detail map showing location of fossil localities. Profile corresponding to line A on map.

Schilder's (1939, p. 31) locality No. 17 is identical with N.V.P. Blue No. 3892.

The type locality of *Marginocypraea paraguana* and *Cypraea fossula* (=University of California locality No. S-8360) is indicated by Ingram (1947, pp. 4, 5) as:

Approximately 300 meters south of Casa Cantaure, which is about 10 km west of Pueblo Nuevo near San José, Paraguaná Peninsula, Venezuela.

The correct spelling of the names "Cantaura" and "Cocodito" is Cantaure and Cocodite according to Brann and Kent (1960, p. 15).

The locality number 3892 does not represent a single outcrop but possibly the area the Renz localities cover. The point 3892 would lie 170 m. north of Re 1148, *i.e.* on the northern slope of the Loma Barbasco. This, however, is not of great importance, because the strata are practically horizontal. The sediments in question do not exceed 75 m. in thickness, and the bulk of the fossils has been found in their middle part.

The geological situation has been described in a letter of H. Bolli to H. G. Kugler, dated January 3d, 1963:

Middle Miocene: the younger Tertiary was closely investigated only in the area of the detail map, west of Pueblo Nuevo. The transgression over granite and Cretaceous was clearly observed there at many localities. The series begins as a rule with a one meter thick oyster and *Balanus* breccia, overlain by gypsiferous marls and clays which often contain a 20-30 cm thick, lenticular layer of brown, sandy limestone, full of fossil remains. The marls locally are rich in well preserved molluscs, and fragments of reef corals are not rare. Above follows a more compact, porous limestone of light brown colour which laterally grades into reef limestone with *Lithothamnium*, well exposed along the Pueblo Nuevo—Bella Vista road. This limestone forms a conspicuous escarpment which was followed south-eastward as far as Miraca.

Mio-Pliocene: the Middle Miocene escarpments are surrounded by more gently dipping sediments, consisting of clays, limestones and sandy limestones. According to our present knowledge, these deposits cover the greatest part of Paraguaná and form the conspicuous escarpment which crosses the southern part of the peninsula from west to east. The fossils collected in the rocks are of Upper Miocene or possibly Pliocene age.

In an enclosure entitled "Précis of 1956 Creole report" (by Sr. Brígido Natera) of a letter from R. M. Stainforth to H. G. Kugler, dated May 28, 1963, the following remarks are given:

Cantaure Formation (unpublished Creole name). Designates sediments in the immediate vicinity of Cantaure. Formerly called "Cerro Pelado,"

but this is not acceptable because (1) lithologies are different, (2) it is impossible to trace one unit into the other, (3) faunas are different. Type locality is "small ravines running south from the Mesa de Cocodite.

Lithology: Clays (60%), sandstones and limestones of variable thickness and color.

The clays are massive, micaceous, slightly silty, and locally contain abundant fossils.

The sandstones are fine-grained, indurated, thinnish bedded; locally they are "salt-and-pepper"; locally they contain large concretions.

The limestones are thinnish bedded, sandy, well indurated, usually fossiliferous.

Thickness: estimated at 75 meters, but no single section is completely exposed.

Relationships: overlaps with strong unconformity on the igneous and Cretaceous rocks of the Mesa de Cocodite.

Is conformably overlain by the blanket limestones, etc. which cover most of the Peninsula (probably middle to upper Miocene).

Age: regarded as early middle Miocene on molluscan evidence, but the fauna contains a surprising number of endemic species.

COMPOSITION OF FAUNA

The following is a list of the molluscs considered in this report. Their occurrence at different localities is indicated. See pages 399-404.

The number of species in the three classes is as follows:

Scaphopoda	2
Pelecypoda	49
Gastropoda	95

Total	146

These 146 species are distributed in 103 supraspecific (genera, subgenera) categories. It should be noted that the material at hand contains but a few small forms. Further systematic collecting in Central Paraguaná would certainly yield another large number of species especially of Micromollusca.

The following 24 species are described as new:

- Nuculana (Saccella) parva
- Nuculana (Saccella) gnomon
- Nuculana (Saccella ?) gracillima
- Nuculana (Politoleda ?) forcatti
- Anadara (Cunearca) inutilis
- Noetia dauleana paraguanensis
- Corbula (Caryocorbula) fortis
- Acmaea ? astroides
- Cirsotrema undulatum
- Crepidula ? (Crepidatella ?) insculpta

Murex (*Siratus* ?) *triangularis*
Eupleura *kugleri*
Fusinus *mithras*
Voluta *vautrini*
Cancellaria (*Euclia*) *werenfelsi*
Cancellaria (*Bivetiella*) *beata*
Trigonostoma *woodringi*
Crassispira *conica*
Knefastia *kugleri*
Borsonia (*Paraborsonia*) *cantaurana*
Conus *wiedenmayeri*
Conus *aristos*
Conus *talis*
Hastula *lissa*

The fauna at hand is relatively rich in species compared, *e.g.* with that from Springvale, Trinidad. Rutsch (1942, p. 176) cited 153 species from that locality. But it should be remembered that more collecting was done at Springvale than in Paraguaná. On the other hand the fauna from Paraguaná has yielded only a quarter of the number of species of the Bowden fauna. This is perhaps due to the fact that the Bowden fauna covers an unusually wide ecological range (Woodring, 1928, p. 38).

It is noteworthy that the Pectinidae are absent among the Paraguaná molluscs, except for a few unidentifiable small fragments. Whether a certain ecological importance has to be attributed to this circumstance is difficult to decide. The Pectinidae are represented generally by large and conspicuous forms and often are among the first specimens to be collected. It is not likely that they have been overlooked by the collectors.

Species	locality	3892	1148	1150	1152	1153	1154	1155	1193	1199
<i>Scaphopoda</i>										
Dentalium (Dentalium) bocasense Olsson										0
Cadulus (Gadila) aff. phenax Pilsbry & Sharp		0	0							
<i>Pelecypoda</i>										
Nuculana (Saccella) parva, n.sp.		0								
Nuculana (Saccella) gnomon, n.sp.		0								
Nuculana (Saccella) aff. gnomon, n.sp.		0								
Nuculana (Saccella ?) gracillima, n.sp.		0								
Nuculana (Polioleda ?) forcatti, n.sp.		0								
Area (Area) umbonata Lamarck		0								
Barbatia (Cucullaearca), n.sp.aff. mississippiensis (Conrad)		0								
Anadara (Cunearca) zorritensis (Spicker)		0								
Anadara (Cunearca) inutilis, n.sp.		0	0				0			0
Anadara (Scapharca) aff. cornellana (H. K. Hodson)		0	0				0			0
Anadara (Scapharca) veatchi matrucana (H. K. Hodson)		0								
Anadara (Scapharca) tirantensis (H. K. Hodson)		0	0		0		0			
Anadara (Scapharca) cf. spikeri (Olsson)		0	0							0
Noetia dauleana paraguayensis n.subspec.		0		0	0			0		
Eontia, n.sp.aff. centrota (Guppy)		0								
Glycymeris (Glycymeris) aff. democraciana F. & H. Hodson		0								
Glycymeris (Glycymeris) aff. jamaicensis Dall		0								
Atrina spec.ind.		0								
Spondylus aff. lucasi Maury		0								
Plicatula cf. guppyi Woodring		0								
Ostrea cf. portoricensis Hubbard									0	
Ostrea aff. aguacilensis paraguayensis F. Hodson		0								

Species	Locality	3892	1148	1150	1152	1153	1154	1155	1193	1199
<i>Ostrea sp.ind.aff. vaughani insularis</i> Brown & Pilsbry		0								
<i>Eucassatella trinitaria venezuelana</i> (F. Hodson)		0								
<i>Cardita paraguensis</i> (F. Hodson)		0								
<i>Chama aff. berjadinensis</i> F. Hodson		0								
<i>Pseudochama quirosana</i> (F. Hodson)		0								
<i>Arcinella yaquensis</i> (Maury)		0								
<i>Trachycardium</i> (Dalloccardia) <i>bowdenense</i> (Dall)		0								
<i>Trigoniocardia</i> (Trigoniocardia) <i>aff. ceramida</i> (Dall)		0								
<i>Trigoniocardia</i> (subgenus ?) <i>hannai</i> (Olsson)		0	0							
<i>Cyclinella venezuelana</i> H. K. Hodson		0	0				0		0	
<i>Clementia</i> (Clementia) <i>dariena</i> (Conrad)		0	0	0	0		0	0	0	0
<i>Macrocallista maculata</i> (Linne)		0								
<i>Pitar</i> (Pitarella) <i>paraguensis</i> (H. K. Hodson)		0	0	0	0	0	0	0	0	0
<i>Pitar</i> (Lamelliconcha) <i>circinatus</i> (Born)		0								
<i>Antigona</i> (Ventricolaria) <i>palmerae</i> H. K. Hodson		0								
<i>Chione</i> (Chionopsis) <i>paraguensis</i> H. K. Hodson		0							0	
<i>Chione</i> (Liriphora) <i>quirosensis</i> H. K. Hodson		0	0		0	0	0	0	0	0
<i>Maetra</i> (Micromactra) <i>maracaibensis</i> H. K. Hodson		0							0	
<i>Maetra</i> (Mactrotoma ?) <i>quirosana</i> H. K. Hodson		0								
<i>Pleuropygia caroniana</i> (Maury)		0								
<i>Semele spec.</i>		0								
<i>Tellina</i> (Eurytellina) <i>paraguensis</i> H. K. Hodson		0							0	
<i>Psammacoma</i> ? <i>cf. falconensis</i> (H. K. Hodson)		0	0			0	0	0	0	0
<i>Psammacoma</i> ? <i>spec.</i>		0								
<i>Corbula</i> (Caryocorbula) <i>fortis</i> , n.sp.		0							0	
<i>Corbula</i> (Caryocorbula) <i>quirosana</i> F. Hodson		0								
<i>Corbula</i> (Tenuicorbula) <i>aff. tenuis</i> lupina Olsson		0								

Species	locality	3892	1148	1150	1152	1153	1154	1155	1193	1199
<i>Gastropoda</i>										
<i>Acmaea</i> ? <i>astroides</i> , n.sp.		0								
<i>Nerita</i> (<i>Nerita</i>) <i>fulgurans</i> Gmelin		0						0		
<i>Neritina</i> aff. <i>woodwardi</i> Guppy		0								
<i>Turritella</i> <i>coodiana</i> F. Hodson		0	0	0	0	0	0	0	0	0
<i>Turritella</i> <i>machapooensis</i> paraguensis F. Hodson		0					0			
<i>Turritella</i> <i>machapooensis</i> wiedenmayeri F. Hodson		0	0							
<i>Turritella</i> <i>gilbertharisi</i> F. Hodson									0	
<i>Turritella</i> <i>matrucana</i> F. Hodson		0	0							0
<i>Turritella</i> cf. <i>venezuelana</i> F. Hodson		0								0
<i>Architectonica</i> (<i>Architectonica</i>) <i>nobilis nobilis</i> Röding		0	0		0		0	0	0	0
<i>Architectonica</i> (<i>Architectonica</i>) <i>nobilis karsteni</i> Rutsch		0	0							0
<i>Potamides</i> <i>suprasulcatus</i> (Gabb)		0								
<i>Rhinoclavis</i> (<i>Ochetoclava</i>) <i>venada</i> (Maury)		0	0	0						0
<i>Scalina</i> <i>pseudoleroyi</i> (Maury)		0								
<i>Cirsotrema</i> <i>undulatum</i> , n.sp.		0								
<i>Hipponix</i> <i>ceras</i> Woodring		0								
<i>Calyptraea</i> (<i>Trochita</i>) cf. <i>radians</i> (Lamarck)		0								
<i>Crucibulum</i> (<i>Dispotaea</i>) <i>waltonense</i> Gardner		0								
<i>Crucibulum</i> (<i>Dispotaea</i>) <i>ecuadorensis</i> Olsson		0								
<i>Crepidula</i> <i>cantaurana</i> F. Hodson		0								
<i>Crepidula</i> ? (<i>Crepidatella</i> ?) <i>insculpta</i> , n.sp.		0								
<i>Cypraea</i> aff. <i>isabella</i> Linné		0								
<i>Marginocypraea</i> <i>wegeneri</i> (Schilder)		0	0	0	0	0	0	0	0	0
<i>Natica</i> (<i>Naticarius</i>) <i>canrena antinacca</i> Cossmann		0	0					0		
<i>Polinices</i> <i>nelsoni</i> Olsson		0								0
<i>Neverita</i> <i>paraguensis</i> F. Hodson		0	0	0			0			0

Species	locality	3892	1148	1150	1152	1153	1154	1155	1193	1199
<i>Sinum gabbi</i> (Brown & Pilsbry)		o								
<i>Sinum dodoneum</i> Gardner		o								
<i>Seonsia laevigata</i> laevigata (G. B. Sowerby, I)		o								
<i>Distorsio</i> (Rhysema) decussata gatunensis Toulia		o								
Bursa (Colubrellina) caelata amphitrites Maury		o		o						o
<i>Malea</i> cf. <i>camura</i> Guppy							o			
<i>Ficus carbasea</i> carbasea (Guppy)		o	o			o		o		o
<i>Murex</i> (Murex) recurvirostris quirosensis F. Hodson		o	o							
<i>Murex</i> (Murex) polynematicus Brown & Pilsbry		o								
<i>Murex</i> (Chitcoreus) cf. <i>brevifrons</i> Lamarck		o								
<i>Murex</i> (Subpterynotus) <i>textilis</i> Gabb		o								
<i>Murex</i> (Siratus ?) <i>triangularis</i> , n.sp.		o								
<i>Paziella</i> (Panamurex ?) cf. <i>gatunensis</i> (Brown & Pilsbry)		o								
<i>Eupleura</i> <i>kugleri</i> , n.sp.		o	o							
<i>Typhis</i> (Laevityphis) <i>sawkinsi</i> Mansfield		o							o	
<i>Cymia</i> <i>buchivacoana</i> cantaurana H. K. Hodson		o								
<i>Cymia</i> <i>cocoditana</i> (H. K. Hodson)		o								
<i>Mitrella</i> <i>quirosana</i> (H. K. Hodson)		o								
<i>Cymatophos</i> <i>cocoditoensis</i> (F. Hodson)		o	o			o	o	o	o	o
<i>Cymatophos</i> <i>paraguanensis</i> (F. Hodson)		o	o			o	o	o	o	o
<i>Pallacera</i> <i>maracaihensis</i> (Weisbord)		o								
<i>Pallacera</i> <i>urumacoensis</i> (F. Hodson)		o								
<i>Antillophos</i> <i>candei</i> gatunensis (Toulia)		o								
<i>Antillophos</i> ? aff. <i>landesi</i> Marks		o								
<i>Antillophos</i> ? spec. A		o								
<i>Melongena</i> <i>melongena</i> consors (G. B. Sowerby, I)		o	o		o	o	o	o		o
<i>Fusinus</i> <i>mithras</i> , n.sp.		o								

Species	locality	3892	1148	1150	1152	1153	1154	1155	1193	1199
<i>Latirus</i> (subgenus ?) cf. <i>tumbeziensis</i> (Olsson)		0	0				0	0		0
<i>Latirus</i> (<i>Polygona</i>) aff. <i>anapetes</i> Woodring		0								
<i>Oliva</i> (<i>Oliva</i>) cf. <i>cylindrica</i> G. B. Sowerby, I			0				0			0
<i>Agaronia</i> <i>testacea</i> <i>costaricensis</i> (Olsson)		0								
<i>Mitra</i> (<i>Tiara</i>) <i>quirosana</i> F. Hodson		0	0						0	0
<i>Turbinella</i> <i>falconensis</i> (H. K. Hodson)		0	0	0	0	0	0	0	0	0
<i>Voluta</i> <i>vautrini</i> , n.sp.										0
<i>Falsilyria</i> <i>spec.ind.</i>		0								
<i>Cancellaria</i> (<i>Cancellaria</i>) <i>epistomifera</i> Guppy		0						0		
<i>Cancellaria</i> (<i>Cancellaria</i> ?) <i>lavelana</i> H. K. Hodson		0								
<i>Cancellaria</i> (<i>Cancellaria</i>) aff. <i>rowelli</i> Dall		0								
<i>Cancellaria</i> (<i>Eulla</i>) <i>werenfelsi</i> , n.sp.		0								
<i>Cancellaria</i> (<i>Bivettella</i>) <i>beata</i> , n.sp.		0								
<i>Cancellaria</i> (subgenus ?) <i>paraguanensis</i> H. K. Hodson		0			0					
<i>Cancellaria</i> (<i>Charcolleria</i>) <i>terryi</i> Olsson		0								0
<i>Trigonostoma</i> <i>woodringi</i> , n.sp.		0								
<i>Prunum</i> (<i>Prunum</i>) <i>quirosense</i> (F. Hodson)		0	0				0	0	0	0
<i>Peisicula</i> (<i>Rabicea</i>) <i>venezuelana</i> <i>lavelana</i> (F. Hodson)		0						0		
<i>Polystira</i> <i>barretti</i> (Guppy)		0	0				0			0
<i>Crassispira</i> <i>henekeni</i> (G. B. Sowerby, I)		0	0							
<i>Crassispira</i> <i>conica</i> , n.sp.		0								
<i>Crassispira</i> aff. <i>consors</i> (G. B. Sowerby, I)		0								
<i>Clathrodrillia</i> <i>puertocolombiana</i> (Weisbord)		0	0				0			0
<i>Clathrodrillia</i> ? n.sp.aff. <i>C. isalindae</i> (Maury)		0								
<i>Fusiturricula</i> cf. <i>jaquensis</i> (G. B. Sowerby, I)		0	0						0	0
<i>Knefastia</i> aff. <i>lavinoides</i> (Olsson)		0						0	0	0
<i>Knefastia</i> <i>kugleri</i> , n.sp.		0	0	0	0			0		0

Species	locality	3892	1148	1150	1152	1153	1154	1155	1193	1199
<i>Glyphostoma dentiferum</i> Gabb		0								
<i>Borsonia</i> (<i>Paraborsonia</i>) <i>cantaurana</i> , n.sp.		0						0		0
<i>Conus wiedenmayeri</i> , n.sp.		0								
<i>Conus</i> aff. <i>molis</i> Brown & Pilsbry			0		0		0			0
<i>Conus trajectionis</i> Maury		0								
<i>Conus aristos</i> , n.sp.		0	0					0		
<i>Conus</i> aff. <i>imitator</i> Brown & Pilsbry		0	0							
<i>Conus talis</i> , n.sp.		0	0					0		
<i>Terebra</i> (<i>Paraterebra</i>) <i>inaequalis</i> G. B. Sowerby, I		0			0		0			0
<i>Terebra</i> (<i>Paraterebra</i>) <i>sulcifera</i> G. B. Sowerby, I		0	0					0		0
<i>Terebra</i> (<i>Strioterebrum</i>) <i>ulloa</i> Olsson		0	0		0			0		0
<i>Terebra</i> (<i>Strioterebrum</i>) spec. A		0	0							
<i>Terebra</i> (<i>Strioterebrum</i>) spec. B										
<i>Terebra</i> (<i>Strioterebrum</i>) spec. C			0							0
<i>Hastula lissa</i> , n.sp.		0								

ECOLOGICAL REMARKS

The fauna from Central Paraguaná represents a tropical shallow-water assemblage. Its tropical character is shown by its generic composition, its geographical position, as well as by the distribution of species, which are still living, and of species of the fauna, whose close relatives and probable descendants make part of the Recent fauna, e.g. *Arca umbonata*, *Nerita fulgurans*, *Architectonica nobilis nobilis*, and *Melongena melongena*.

The neritic character is obvious. There is no deep-water genus such as *Seguenzia* or *Cocculina*. Clarke (1962) cited species of genera, e.g. *Dentalium*, *Cadulus*, *Nuculana*, *Marginella*, and *Natica* which reach down into the abyssal region, but representatives of those genera are found in the neritic zone also. The presence of *Potamides*, *Nerita*, and *Neritina* points to proximity of the coast.

The character of the bottom was certainly not uniform at the time of deposition. With the exception of forms that prefer sandy bottom as do *Oliva* or the Naticidae, there are genera, which are attached to some substratum during part of or the whole span of their life, e.g. *Spondylus*, *Plicatula*, *Chama*, *Pseudochama*, *Arcinella*, and *Ostrea*. The Calyptraeidae, which are fairly well represented in the Paraguaná material, are attached to stones. On the other hand boring pelecypods such as *Lithophaga*, *Petricola*, or *Pholas* are missing.

The bulk of the Paraguaná forms seems to have lived in water of normal salinity. This is indicated by the analogous occurrence of Recent species which are either identical or closely related to the fossils. The presence of *Nerita* and *Potamides* shows that there must have been some brackish influence. Russell (1941, p. 364) wrote:

Nerita fulgurans Gmelin is only found where there is a moderate amount of brackish water . . . Conditions of this sort only exist where there are fairly sizable rivers entering rather large harbor enclosures, where the admixture of salt and fresh water is more or less constant at all times.

And Abbott (1954, p. 129) stated apropos *Nerita fulgurans*:

This is a salt to brackish-water inhabitant of protected shores, and is abundant only in certain restricted localities.

ASSOCIATED ORGANISMS

Associated with the molluscan collection are a few specimens of *Balanus* and corals, numerous otoliths belonging to two or three different forms, and two fragments of a *Callianassa*.

Miller and Thompson (1937, p. 69, pl. 9, figs. 1-4; pl. 10, figs. 1,2) and Miller (1947, p. 93) recorded *Aturia curvilineata* Miller and Thompson from locality 3892 (= holotype locality). This species is known also from the Guaracara limestone member of the Concord Quarry at Pointe-à-Pierre, Trinidad. According to personal information from H. G. Kugler the Guaracara limestone member belongs in the Tamana formation (and not in the Brasso formation as stated by Miller on information received). The Guaracara limestone member is between the *Globorotalia mayeri* and the *Gr. menardii* Zones. Further on Miller recorded *A. curvilineata* from "strata mapped as Lower Miocene between the Peninsula of Santa Elena and the city of Guayaquil, Ecuador."

COMPARISON WITH OTHER FAUNAS AND CONCLUSION
AS TO AGE

As shown on Table 1 the following formations have the highest number of species in common with the fauna from Central Paraguaná: Miocene (undifferentiated) of Colombia (12), the Gatún formation of Panamá (14), the Gatún formation of Costa Rica (10), and the Cercado (11) and Gurabo (12) formations of the Dominican Republic. If Cercado and Gurabo formations are taken together this number is increased to 14. The above mentioned formations are generally put in the middle Miocene. An age assignment of middle Miocene on the basis of affinities to the faunas from Panamá and those from the Dominican Republic is apparent. This is also confirmed by the stratigraphic distribution of some species shown in Table 2.

Among the few species that also occur in lower Miocene strata, three long-ranging forms are still living in the Caribbean sea: *Arca umbonata*, *Macrocallista maculata*, and *Architectonica nobilis nobilis*. *Dentalium bocasense* has been recorded from the La Rosa formation (lower Miocene) by Sutton (1946, p. 1696).

Table 1. Distribution of some *Parnassana* species.

Occurrence	Number of species in genus											
	Venezuela	Colombia	Peru	Ecuador	Panama	Costa Rica	San Domingo	Jamaica	Trinidad	Puerto Rico	Florida	
Species from Central Paraguaná												
Dentalium bocacensis												
Arca (Arca) umbonata												
Anadara (Cunearca) zorrillensis												
Anadara (Scapharca) ventchi maffucciana												
Eucrassatella trinitaria venezuelana												
Cardita quirosana												
Pseudochama quirosana												
Echinochama yaquensis												
Trachycardium (Dalloccardium) bostonense												
Trigonocardia bannai												
Clementia (Clementia) darwina												
Macrocallista maculata												
Pitar (Lamelliconcha) circinatus												
Chione (Chionopsis) paraganensis												
Chione (Liraphora) quirosensis												
Nacra (Nactrotoma ?) quirosana												
Pleurotylis carolinana												
Corbula (Curvucorbula) quirosana												
Aerita (Aerita) fulgurans												
Turritella maffucciana												
Architectonica nobilis nobilis												
Architectonica nobilis karsfordi												
Potamides suprasulcatus												
Rhinoclavis (Gchotoclava) venusta												
Scallina pseudoleprovi												
Hippinx ceras												
Crucibulum (Disputaea) walttonense												
Crucibulum (Disputaea) ecuadorense												
Naraiuceptaea sinuocori												
Natica (Naticarius) eumena bolinaeae												
Polinices nelsoni												
Neveritia paraganensis												
Sinum gibbi												
Sinum dodoneum												
Sconsia laevigata laevigata												
Distorsio decussata gatunensis												
Bursa caelata amphitres												
Ficus caribaea caribaea												
Murex recurvirostris quirosensis												
Murex polymenaticus												
Murex (Subperlynotus) textilis												
Typhis (Laevityphis) savinski												
Mitrella quirosana												
Caloplos maracubensis												
Antillopsis candei gatunensis												
Melongena melongena consors												
Agaronia testacea costaricensis												
Mitra (Tiara) quirosana												
Cancellaria epistomifera												
Cancellaria (Charcollieria) terryl												
Prunum (Prunum) quirosense												
Persicula (Rabicea) venezuelana												
Polystira barretti												
Crassispira henekeni												
Clathrodrillia puertocolombiana												
Glyptostoma dentiferum												
Conus trajectorynis												
Terebra (Paraterebra) inaequalis												
Terebra (Paraterebra) sulcifera												
Terebra (Strioterebra) ulloa												

Table 2. Stratigraphic distribution of some Paraguaná species, the stratigraphic occurrence of which elsewhere in the Caribbean region is sufficiently known

	Lower Miocene	Middle Miocene	Upper Miocene	Pliocene	Recent
Dentalium bocasense					
Arca (Arca) umbonata					
Anadara (Cunearca) zorritensis					
Arcinella yaquensis					
Trachycardium (Dallocardia) bowdenense					
Trigoniocardia hannah					
Clementia (Clementia) dariena					
Macrocallista maculata					
Pitar (Lamelliconcha) circinatus					
Pleiorytis caroniana					
Nerita (Nerita) fulgurans					
Turritella matarucana					
Architectonica nobilis nobilis					
Architectonica nobilis karsteni					
Potamides suprasulcatus					
Rhinoclavis (Ochetoclava) venada					
Scalina pseudoleroyi					
Hipponix ceras					
Crucibulum (Disputaea) waltonense					
Crucibulum (Disputaea) ecuadorensis					
Marginocypraea wegneri					
Natica (Naticarius) canrena antinacca					
Polinices nelsoni					
Sinum gabbi					
Sinum dodoneum					
Sconsia laevigata laevigata					
Distorsio decussata gatunensis					
Bursa caelata amphitrites					
Ficus carbacea carbacea					
Murex polynematicus					
Murex (Subpterynotus) textilis					
Tvphis (Laevityphis) sawkinsi					
Antillophos candei gatunensis					
Melongena melongena consors					
Agaronia testacea costaricensis					
Cancellaria epistomifera					
Cancellaria (Charcolleria) terryi					
Polystira barretti					
Crassispira henekeni					
Glyphostoma dentiferum					
Conus trajectonis					
Terebra (Paraterebra) inaequalis					
Terebra (Paraterebra) sulcifera					
Terebra (Strioterebrum) ulloa					
Aturia curvilineata					

Terebra (*Strioterebrum*) *ulloa* is listed from lower Miocene strata of Perú (lower Zorritos formation) and Ecuador (Subibaja formation). Its occurrence in Paraguaná is the first record for the middle Miocene.

All the other species that appear in the lower Miocene, *i.e.* *Clementia* (*Clementia*) *dariena*, *Potamides suprasulcatus*, *Ficus carbasea carbasea*, and *Melongena melongena consors*, are known also from middle Miocene deposits outside Paraguaná.

The number of species, which range from middle Miocene to higher horizons, is greater than that of species appearing in the lower Miocene. Among these species may be mentioned: *Pleiorytis caroniana*, *Turritella matarucana*, *Architectonica nobilis karsteni*, *Polinices nelsoni*, *Sconsia laevigata laevigata*, *Distorsio decussata gatunensis*, *Bursa caelata amphitrites*, *Murex* (*Subpterynotus*) *textilis*, *Antillophos candei gatunensis*, and *Cancellaria* (*Charcoleria*) *terryi*.

The indication of the stratigraphic range of some species mentioned above is based on so-called clearly determinable species. But because every determination is subjective and thus has to be taken *cum grano salis*, it may be of equal value to consider the affinities of those forms that have been treated by means of the *nomenclatura aperta*. Among these species (which represent a considerable part of the collection) are forms that stand in the morphological vicinity of typical middle Miocene species such as *Paziella* (*Panamurex* ?) cf. *gatunensis*, *Crassispira* aff. *consors*, *Knefastia* aff. *lavinoides*. Others, however, show affinities to species clearly younger than middle Miocene, *e.g.* *Eontia*, n.sp. aff. *centrota*, *Corbula* (*Tenuicorbula*) aff. *tenuis lupina*, *Latirus* cf. *tumbeziensis*, *Latirus* (*Polygona*) aff. *anapetes*.

On the other hand the differences between the fauna from Paraguaná and the faunas of the Punta Gavilán and Springvale formations, both of late Miocene age, are well marked. Both faunas have only five species in common with that from Paraguaná. Typical upper Miocene species such as *Amusium mortoni* and *Ostrea* (*Lopha*) *messor* are missing.

According to Woodring (1960, p. 30), the middle and upper parts of the Gatún formation of Panamá, the Gurabo formation

of the Dominican Republic and the Bowden formation of Jamaica are correlated, and an upper middle Miocene age is assigned to them. The close relation to the faunas of those formations, except perhaps the Bowden fauna (see below), and the occurrence of *Sconsia laevigata laevigata* (see Maury's 1917 *Sconsia laevigata* Zone = Gurabo formation) suggests an upper middle Miocene age for the fauna from Paraguaná. This view is supported by the presence of *Aturia curvilineata* which is recorded also from the Guaracara limestone member of the Tamana formation of Trinidad. The Guaracara limestone member lies between the *Globorotalia mayeri* and the *Gr. menardii* Zones. In Falcón (Venezuela) the *Gr. mayeri* and the *Gr. menardii* Zones are put in the Husito marly clay member of the Pozón formation (Blow, 1959, chart preceding p. 75).

According to discussions during the Congress of the "Comité du Néogène Méditerranéen" held in Bern (June 8-13, 1964) the *Globorotalia mayeri* Zone includes the uppermost part of the "Elveziano" (not Helvetian) and the lowermost part of the Tortoniano, and the *Gr. menardii* Zone falls entirely in the Tortoniano (at the type section of the Tortonian: Rio Mazzapiedi near Sant' Agata Fossili).

The Bowden fauna is of about the same age. Brönnimann (1952, p. 36) stated:

It appears from the distribution of the pelagic species that the *Globorotalia mayeri* Zone can be correlated with part of the Bowden Formation of Jamaica which, on the basis of mollusks, is of high Middle Miocene or lowermost Upper Miocene age.

There are only eight species from Paraguaná that also occur at Bowden. Other forms closely resemble Bowden species, e.g. *Glycymeris* aff. *jamaicensis*, *Plicatula* cf. *guppyi*, and *Neritina* aff. *woodwardi*. Panamá, Bowden, and the type sections of the middle Miocene of the Dominican Republic all lie at about the same distance from Paraguaná. It seems astonishing that the fauna in the west (Panamá) and the fauna in the north (Dominican Republic) are more closely related than that in the northwest (Bowden).

Although clearly related to outside faunas, the Paraguaná assemblage exhibits a remarkable degree of endemism. Nineteen species in this collection were cited by the Hodsons from their

locality No. 2207. Most of the species listed below are restricted to Paraguaná:

Anadara (Scapharca) veatchi matarucana (H. K. Hodson)
 Cardita paraguanensis (F. Hodson)
 Cyclinella venezuelana H. K. Hodson
 Pitar (Pitarella) paraguanensis (H. K. Hodson)
 Chione (Chionopsis) paraguanensis H. K. Hodson
 Tellina (Eurytellina) paraguanensis H. K. Hodson
 Turritella cocoditana F. Hodson
 Turritella machapoorensis paraguanensis F. Hodson
 Architectonica nobilis nobilis Röding
 C. epidula cantaurana F. Hodson
 Neverita paraguanensis F. Hodson
 Cymia buchiyacoana cantaurana H. K. Hodson
 Cymia cocoditana H. K. Hodson
 Cymatophos cocoditoensis (F. Hodson)
 Cymatophos paraguanensis (F. Hodson)
 Turbinella falconensis (H. K. Hodson)
 Cancellaria paraguanensis H. K. Hodson
 Prunum (Prunum) quirosense (F. Hodson)
 Persicula (Rabicea) venezuelana lavelana (F. Hodson)

Hodson indicated the age of his locality No. 6 (Quiroz) as Oligocene-Miocene (compare Stratigraphical Lexicon of Venezuela, Bol. Geologia, Spec. Pub. No. 1, 1956, p. 290). As shown on Table 1, 10 species are common to Quiroz and Central Paraguaná. Hodson cited his *Prunum quirosense* from his localities 6 and 2207. The relatively large number of species common to both localities strongly suggests a much younger age of the Quiroz assemblage, which belongs in the La Rosa formation (lower Miocene).

Hodson attributed an early Miocene age to the fauna of his locality No. 2207. Senn (1935, p. 80, correlation chart) stated that the rich molluscan fauna from Cantaure, Paraguaná, belongs in the lower part (Querales shales) of the Socorro formation, which he thought is of early Miocene age. In Wheeler's publication (1963, p. 67) the Querales formation is put at the base of the middle Miocene. Schilder (1939, p. 31), based on his *Sphaerocypraea wegneri*, estimated that his locality No. 17 (= N.V.P. Blue No. 3892 $\cong$ Hodson locality No. 2207) might be slightly younger than his locality No. 5 (Adivinanza Estate), which falls in the St. Croix member of the Brasso formation of Trinidad, and which is assumed to belong to the *Globigerinatella insueta* Zone. Ingram (1947, p. 1) indicated a late Miocene age for the University of California

locality No. S-8360, which corresponds almost exactly with N.V.P. Blue No. 3892.

The method of age assignments on the basis of the percentage of still living species in a fossil assemblage meets with great difficulties. Woodring (1928, pp. 106-7) discussed these difficulties and gave a list of percentages of living species in different Miocene strata. Petzall (1959, p. 291; citing Marks) gave a list of 12 species from the Caujarao formation that are still living. These represent 13% of the whole fauna and agree reasonably well with Woodring's indications for middle Miocene percentages. Some of the identifications of this list, however, seem to be somewhat doubtful. In the same article the fauna of the Caujarao formation is correlated with the Gurabo formation of the Dominican Republic, and the Gatún formation of Panamá and Costa Rica, and is thought to be slightly older than the Bowden fauna.

SYSTEMATIC PALEONTOLOGY

Class SCAPHOPODA

Family DENTALIIDAE

Genus DENTALIUM Linné

Linné, 1758, *Systema Naturae*, ed. 10, p. 785.

Type species (by subsequent designation, Montfort, 1810, *Conchyliologie systématique*, vol. 2, p. 23), *Dentalium elephantinum* Linné.

Subgenus DENTALIUM s. str.

Dentalium (Dentalium) bocasense Olsson

Pl. 50, fig. 1

1922. *Dentalium* (*Dentalium*) *bocasense* Olsson, *Bull. Amer. Paleont.*, vol. 9, No. 39, p. 166, pl. 15, figs. 2, 3.

1946. *Dentalium bocasense* Olsson, Sutton, *A.A.P.G. Bull.*, vol. 30, No. 10, p. 1696 (list).

Addenda to Olsson's original description.—In young stages the longitudinal, equidistant ribs are somewhat sharpened but become more rounded with increasing age. Their interspaces are strongly concave at the anal, flat at the oral aperture. The regular increase of the diameter—and thus the regular outline—may be interrupted by conspicuous growth lines which make a slight constriction of the shell. Secondary ribs are generally of the same

size as the primaries, but there are specimens with clearly larger primaries than secondaries.

Syntypes.—Pal. Res. Inst., Ithaca, New York, Nos. 21116, 21117.

Remarks.—On an average the numerous specimens are smaller than those from Panamá. The largest shell at hand (G 11315) measures 33 mm. in length with a maximum diameter of 3.7 mm. The corresponding measurements of Olsson's smaller figured specimen are 44 mm. and 4.75 mm. respectively. But otherwise Olsson's description agrees with the material studied.

Comparisons.—*D. bocasense* has a hexagonal type of sculpture. The sculptural symmetry, however, does not always remain constant. *D. gabbi* Pilsbry and Sharp (1898, p. 470, pl. 10, figs. 6, 7, 13; pl. 11, figs. 1, 2) from the Miocene of the Dominican Republic has a hexagonal apex, but the irregular appearance of secondary ribs disturbs the symmetry of cross sections. The shell tapers more rapidly than *D. bocasense*, and it is less curved. *D. cossmannianum* Pilsbry and Sharp (1898 p. 467, pl. 10, fig. 11; pl. 11, figs. 10, 11), another hexagonal species, differs by its narrow, sharp, and widely spaced ribs. Specimens from Bowden at hand are much smaller as a whole. The Recent *D. rebeccaense* Henderson (1920, p. 31, pl. 3, fig. 2) has coarser ribs than *D. cossmannianum* and differs from *D. bocasense* in having no secondary sculpture. Other hexagonal forms belong to the groups of *D. texasianum* with its subspecies and *D. gouldii* with its subspecies (compare Henderson, 1920, pp. 27-31).

Occurrence.—N.V.P. Blue No. 3892, Re 1148, Re 1199.

Distribution.—Gatún formation of the Bocas del Toro Island, Panamá. La Rosa formation of the Maracaibo Basin, Venezuela.

Family SIPHONODONTALIIDAE

Genus CADULUS Philippi

Philippi, 1844, Enumeratio molluscorum Siciliae, vol. 2, p. 209.

Type species (by monotypy), *Dentalium ovulum* Philippi.

Subgenus GADILA Gray

Gray, 1847, Zool. Soc. London, Proc., pt. 15, p. 159.

Type species (by original designation), *Dentalium gadus* Montagu.

Cadulus (Gadila) aff. phenax Pilsbry and Sharp

Pl. 50, fig. 2

1898. *Cadulus phenax* Pilsbry and Sharp, Acad. Nat. Sci. Philadelphia, Proc. for 1897, p. 472, pl. 11, figs. 23, 24.

Type.—Acad. Nat. Sci. Philadelphia?

Remarks.—The present specimens have practically the same outline as indicated by the original figures of *C. phenax*. Unfortunately Maury's figure (1917, pl. 26, fig. 5) is useless for the recognition of surface details. *C. phenax* is said to have no corrugations or circular riblets on the posterior part of the shell. Some of the fragments (G 11316/1-4), however, have weak and somewhat oblique circular riblets in young stages. The degree of the constriction of the oral aperture is about the same.

Comparisons.—*C. dentalinus* (Guppy) (1873a, p. 87, pl. 1, fig. 11) from Bowden, Jamaica, of which many specimens are at hand, clearly differs from this form by its prominent circular corrugations in the young stage and the stronger swelling near the oral aperture. *C. dentalinus* is the type of Woodring's *Gadilopsis*, which is placed in the synonymy of *Gadila* by Emerson (1962, p. 478). *C. hendersoni* Woodring (1925, p. 207, pl. 28, fig. 4) probably represents a large specimen (only the holotype is known) of *C. dentalinus* and cannot be considered as a distinct species, judging from the variability of the shells from Paraguaná. The intensity of the circular riblets, and the stoutness of the whole shell is variable. *C. leptodoma* Pilsbry and Olsson (1941, p. 49, pl. 10, fig. 11) from the Canoa formation (Pliocene) of western Ecuador is a similar species. It has about the same size, outline, and mode of enlargement. Its weak posterior circular riblets are irregularly set, whereas those of these specimens are regular. Two similar Recent species are *C. acus* Dall (1889, p. 432, pl. 27, fig. 11) from Samana Bay, Dominican Republic, and *C. panamensis* Pilsbry and Sharp (1897, 1898, p. 191, pl. 36, figs. 23-25) from the Pacific Coast of Central America.

Occurrence.—N.V.P. Blue No. 3892.

Class PELECYPODA

Family NUCULANIDAE

Genus NUCULANA Link

Link, 1807, Beschreibung der Naturalien-Sammlung der Universität zu Rostock, p. 155.

Type species (by monotypy), *Arca rostrata* Chemnitz (= *Mya permula* Müller).

Subgenus **SACCELLA** Woodring

Woodring, 1925, Carnegie Inst. Wash., Pub. No. 366, p. 15.

Type species (by original designation), *Arca fragilis* Chemnitz (= *Leda commutata* Philippi).

Nuculana (Saccella) parva, n. sp.

Pl. 50, figs. 3-7

Shell small. Umbones low, opisthogyrate. Anterior margin strongly rounded, posterior end pointed. Ventral margin evenly arched. Lunule small and badly defined. A sharp ridge extends from the umbones to the posterior end which is followed anteriorly by a shallow depression. Another, but low ridge, runs from the umbones to the antero-ventral margin marking the anterior border of a second shallow depression. Sculpture consisting of about 10 prominent concentric ridges, their interspaces being broader and concave. The concentrics are strongest developed on the middle portion of the shell. They are nearly flat-topped on the anterior part and weak on the posterior keel and the area behind it. Anterior series of teeth (about 15 in number) somewhat longer than posterior one (about 11). Chondrophore small; exterior concentric ridges well visible on interior surface.

Holotype.—Basel Natural History Museum, No. G 11253.

Dimensions of holotype.—Length 4.7 mm; height 2.8 mm.

Remarks.—The above description is based on three right valves. The low number of concentric ridges and the sharp posterior keel are distinctive. The pallial sinus is hardly recognizable. It is moderately deep and directed upwards.

It is possible that the valves are immature. Several species with discrepant juvenile and adult sculptures have been described, but the material does not seem assignable to anyone of these forms.

Comparisons.—*N. trochilia* (Dall) (1898, p. 590, pl. 32, figs. 4, 12) from the *Eophora* Zone (upper Miocene) of Florida is less inequilateral, has more and finer concentric ribs, a deeper depression in front of the posterior keel and a better defined lunule. *N. choctawhatcheensis* (Mansfield) (1916, p. 604, pl. 113, figs. 2, 4)

from the *Arca* Zone (upper middle Miocene) of Florida also has few prominent concentrics, but it lacks the low radial ridge on the anterior portion of the shell. The number of teeth is the same in both rows of teeth, whereas in *N. parva* the anterior series is longer. *N. parva* also resembles the young of *N. diphya* (Gardner) (1926, p. 19, pl. 4, figs. 13-15) from the Chipola formation of Florida. Gardner's figure 15 shows an immature specimen which does not seem to have the anterior radial ridge. Its posterior keel is nearly straight, whereas in *N. parva* it is slightly arched. *N. proteracuta* (Gardner) (1926, p. 13, pl. 2, figs. 17, 18) from the Chipola formation of Florida has the same dimensions, general outline and hinge features as *N. parva* but differs by its less accentuated posterior keel and the greater number of concentric ribs.

Occurrence. — N.V.P. Blue No. 3892.

***Nuculana (Saccella) gnomon*, n. sp.**

Pl. 50, figs. 8-10

Shell small, inequilateral. Umbones low, opisthogyrate. Antero-dorsal margin slightly convex continuing into the strongly curved anterior margin. Posterior extremity pointed. Postero-dorsal margin nearly straight from umbo down to the posterior end. Lunule narrow and indistinct. Concentric sculpture consisting of about 15 ribs which are most prominent on the middle part of the shell disc, *i.e.* where it is most inflated. On the umbo the ribs are weak and partly indistinct. Interspaces narrower than or as wide as the ribs. Towards the gently curved posterior keel the ribs become less pronounced and somewhat narrower. Area behind the posterior keel sculptured by fine threads. In front of the keel there is a broad and shallow depression. A narrow radial ridge extends from the umbo to the antero-ventral extremity which is accentuated by another shallow depression just posterior to it. Chondrophore triangular, small. Anterior row of teeth (about 15) longer and narrower than posterior one (about 11). Pallial sinus moderately deep, directed upwards.

Holotype. — Basel Natural History Museum, No. G 11256.

Dimensions of holotype. — Length 5.1 mm.; height 2.9 mm.

Remarks. — The above description is based on the holotype and six paratypes. The posterior keel of a few paratypes is less

sharp, and the depression anterior to it shallower. The prominence of the concentric ribs is also somewhat variable.

Paratypes have been sent to the British Museum (Natural History), the Paleontological Research Institution, Ithaca, New York, and the U.S. National Museum, Washington, D.C.

Comparisons.—This species resembles *N. parva*, n.sp. It practically differs from it only in the characters of the concentric sculpture on the middle portion of the shell. *N. parva* has fewer and much stronger ribs. The difference between these two species corresponds with that between *N. choctawhatcheensis* (Mansfield) (1916, p. 604, pl. 113, figs. 2, 4) and *N. choctawhatcheensis vaughanensis* (Mansfield) (1932a, p. 32, pl. 1, figs. 14, 17), both from the same locality in the *Arca* Zone (upper middle Miocene) of Florida. It is possible that the form with few and prominent ribs represents an extreme variable, but because there are no transitional specimens in this material, the separation of the two forms seems, at least provisionally, advisable. *N. dodona* (Dall) (1898, p. 589, pl. 32, fig. 6) from the Oak Grove sand of Florida is larger, has more ribs, and the anterior concavity on the shell disc is much wider. Other species of the Alum Bluff group of Florida, as *N. leptalea* (Gardner) (1926, p. 16, pl. 3, figs. 7, 8) and *N. polychoa* (Gardner) (1926, p. 17, pl. 3, figs. 9, 10), are comparable in size, general outline, and hinge features but differ in having many more ribs and a less accentuated posterior keel. The Recent *N. acrita* (Dall) (1908, p. 374; Olsson 1961, p. 60, pl. 2, fig. 7) from Panamá Bay has a less prominent posterior keel and many more ribs.

Occurrence.—N.V.P. Blue No. 3892.

***Nuculana* (*Saccella*) aff. *gnomon*, n.sp.**

Remarks.—A few valves (G 11259/1-3) which are practically identical in size, shape, and hinge features with *N. gnomon*, differ from it in the characters of the external sculpture. Instead of relatively high ribs with interspaces of about the same width as the ribs, this form has flattened ribs with narrow interspaces. On the anterior portion of the shell the sculpture consists of concentric grooves rather than of closely set ribs. The depression extending

from the umbo to the antero-ventral margin is less conspicuous than in *N. gnomon*.

Occurrence.—N.V.P. Blue No. 3892.

***Nuculana (Saccella ?) gracillima*, n.sp.**

Pl. 50, figs. 11-13

Shell medium in size, inequilateral. Umbones low, opisthogyrate. Central part of shell strongly inflated. Posterior end pointed. Postero-dorsal side nearly straight. Antero-dorsal margin slightly convex. Anterior extremity strongly curved. Ventral margin evenly rounded continuing nearly straight to the posterior production. Posterior ridge somewhat curved, smooth in young, partly crenulated in adult stages. Escutcheon sculptured by fine ribs parallel to the hinge margin. Lunule narrow, bordered by an indistinct rounded ridge, which nearly disappears in the adult stage. There is no radial ridge or depression extending from the umbo to the antero-ventral margin. Concentric sculpture divided into three parts. On the umbo it consists of about six weak riblets with slightly wider interspaces. The next eight ribs are prominent and have much broader interspaces. They disappear entirely towards the posterior ridge. The last 16 ribs are narrower, closer-set, and some of them continue over the posterior ridge as crenulations. Both series of teeth have about the same length and number of teeth (15). The anterior series is broader. Chondrophore triangular, moderately large. Pallial sinus hardly recognizable, but apparently not deep.

Holotype.—Basel Natural History Museum, No. G 11260.

Dimensions of holotype.—Length 14.2 mm.; height 8.0 mm.; diameter 3.2 mm.

Remarks.—The holotype, a left valve, is the only specimen of this species. Its anterior extremity is slightly damaged, but otherwise it is well preserved. The three types of concentric sculpture are distinctive.

Comparisons.—The much smaller *N. parva*, n.sp., which has been suspected to represent a young stage only, has a different early sculpture. Its prominent ribs appear earlier. Moreover its posterior ridge is sharper, and it has a depression extending from the umbo to the antero-ventral margin, whereas in *N. gracillima* the surface of this part of the shell is regular. *N. leiorhyncha* (Gard-

ner) (1926, p. 19, pl. 3, figs. 13, 14) from the Shoal River formation of Florida has the same general appearance but is much smaller and has an antero-ventral, radial depression. Another similar species is *N. diphya* (Gardner) (1926, p. 19, pl. 4, figs. 13-15) from the Chipola formation of Florida. It differs from *N. gracillima* by its smaller size, the more upwards pointing posterior extremity, and the radial, antero-ventral depression. Its hinge has more teeth; the anterior series is more curved (concavity ventrally), and the posterior one concave (concavity facing upwards) instead of straight. The Recent West Coast *N. impar* (Pilsbry and Lowe) (1932, p. 106, pl. 17, figs. 3-6) has similar dimensions and also three types of concentric sculpture, but an antero-ventral depression, a broader posterior keel, and another depression just posterior to it.

Occurrence. — N.V.P. Blue No. 3892.

Subgenus **POLITOLEDA** Hertlein and Strong

Hertlein and Strong, 1940, Zoologica, N. Y. Zool. Soc., vol. 25, pt. 4, p. 397.

Type species (by original designation), *Nucula polita* G. B. Sowerby I.

Nuculana (Politoleda ?) forcarti, n. sp.

Pl. 50, figs. 14, 15

Shell of medium to large size, not strongly inequilateral. Beaks opisthogyrate. Antero-dorsal side convex, anterior extremity strongly and regularly rounded, ventral margin evenly curved, posterior end pointed, postero-dorsal margin straight. Posterior ridge broadly rounded. Escutcheon concave, sculptured by distinct ribs subparallel to hinge margin and the weak incrementals. Lunule long and narrow, its bordering ridge low. External surface smooth on the umbonal region except for minute lines. Rest of shell covered with numerous concentric ribs which disappear on the antero-dorsal area, and narrow interspaces. Interspaces on escutcheon wider. Near the posterior ridge and on some restricted areas on the disc the ribs become somewhat oblique to the fine incremental lines. In front of the umbonal ridge they disappear. Sculpture on posterior ridge consists of incrementals only. The shallow depression in front of the posterior ridge causes a little sinus of the postero-ventral margin, thus accentuating the posterior produc-

tion. There is no anterior depression. Hinge: 30 teeth anteriorly, 24 teeth posteriorly. Anterior row slightly curved (concavity ventrally), posterior row straight. Chondrophore large, triangular, slightly extended anteriorly. Pallial sinus deep, its axis subparallel to postero-dorsal margin.

Holotype.—Basel Natural History Museum, No. G 11261.

Dimensions of holotype.—Length 25.5 mm.; height 12.3 mm.; diameter 4.7 mm.

Remarks.—This species is represented only by the holotype, a right valve. A correct subgeneric assignment of this species is difficult. It seems to be intermediate between *Politoleda* (see also Olsson, 1961, p. 66) and *Calorhadia* Stewart (1930, p. 51; see also Stenzel, Krause, and Twining, 1957, pp. 46-59). The sculpture running obliquely to the incrementals is not developed so far as in *N. polita* (for figures see Hertlein and Strong, 1940, pl. 2, fig. 9; Olsson, 1961, pl. 2, figs. 1, 1a). On the other hand the type species of *Calorhadia*, *N. pharcida* (Dall) (1898, p. 587, pl. 32, fig. 8; Stewart, 1930, pl. 8, fig. 2), has two rostral keels, which is not the case in *N. forcarti*. This form is less inequilateral than *N. guppyi* (Dall) (in Guppy and Dall, 1896, p. 329) (= *Cercomya ledaeformis* Guppy, 1866b, p. 581, pl. 26, fig. 1) which has also two posterior ridges. *N. guppyi* belongs to the subgenus *Costelloleda* Hertlein and Strong (1940, p. 398, pl. 2, fig. 10), the type species, *Nucula costellata* G. B. Sowerby I (1832, 1833, p. 198) of which has been placed in the synonymy of *Calorhadia* by Stenzel, Krause, and Twining (1957, p. 48).

Comparisons.—The produced anterior part of the shell is similar to that of *N. balboae* (Brown and Pilsbry) (1911, p. 362, pl. 27, fig. 8) from the Gatún formation of Panamá and Costa Rica. This species, however, is much less produced posteriorly and has no lunule. The description of *N. basilissa* (Gardner) (1926, p. 11, pl. 2, figs. 11, 12) from the Shoal River formation of Florida is based on a fragment. If Gardner's interpretation of the complete form is correct, the shell differs from it in being less inequilateral and in having a straight instead of curved postero-dorsal margin.

Occurrence.—N.V.P. Blue No. 3892.

Family **ARCIDAE**Genus **ARCA** Linné

Linné, 1758, *Systema Naturae*, ed. 10, p. 693.

Type species (defined by Opinion 189, Opinions and declarations rendered by the Internat. Comm. Zool. Nomenclature, vol. 3, pp. 93-108, 1945), *Arca noae* Linné.

Subgenus **ARCA** s. str.**Arca (Arca) umbonata** Lamarck

Pl. 51, figs. 2, 4

1811. *Arca umbonata* Lamarck, *Histoire naturelle des animaux sans vertèbres*, vol. 6, p. 37.

1847. *Arca umbonata* Lamarck, Philippi, *Abb. Besch.*, vol. 3, p. 14, pl. 4, figs. 3a-c.

1892. *Arca umbonata* Lamarck, Dall, *Wagner Free Inst. Sci., Trans.*, vol. 3, pt. 4, p. 620. 1900: *idem*, pt. 5, pl. 38, figs. 4, 4a.

1901. *Arca umbonata* Lamarck, Dall and Simpson, U. S. Fish Commission, *Bull.* for 1900, vol. 1, p. 460.

1917. *Arca umbonata* Lamarck, Sheldon, *Palaeont. Amer.*, vol. 1, No. 1, p. 8, pl. 1, figs. 12-17.

1917. *Arca umbonata* Lamarck, Maury, *Bull. Amer. Paleont.*, vol. 5, No. 29, p. 163, pl. 30, fig. 11.

1920. *Arca umbonata* Lamarck, Maury, *New York Acad. Sci., Sci. Sur. Porto Rico*, vol. 3, pt. 1, p. 6.

1922. *Arca umbonata* Lamarck, Olsson, *Bull. Amer. Paleont.*, vol. 9, No. 39, p. 182, pl. 22, fig. 2.

1926. *Arca umbonata* Lamarck, Gardner, *U.S. Geol. Sur., Prof. Paper 142-A*, p. 24.

1927. *Arca umbonata paczensis* H. K. Hodson, *Bull. Amer. Paleont.*, vol. 13, No. 49, p. 3, pl. 1, fig. 7.

1937. *Arca (Arca) umbonata* Lamarck, Mansfield, *State of Florida, Dept. Cons., Geol. Bull. No. 15*, p. 193.

1940. *Arca umbonata* Lamarck, Perry, *Bull. Amer. Paleont.*, vol. 26, No. 95, p. 31, pl. 2, fig. 10. Revised and enlarged edition 1955, p. 35.

1953. *Arca (Arca) umbonata* Lamarck, Olsson and Harbison, *Acad. Nat. Sci. Philadelphia, Monograph No. 8*, p. 32.

1954. *Arca umbonata* Lamarck, Abbott, *American Seashells*, p. 342, pl. 27j.

Remarks.—Several synonymies of *A. umbonata* include *Barbatia bonaczyi* Gabb (1873b, p. 254) and *A. listeri* ? Philippi of Heilprin (1887, p. 118). Heilprin stated that "*B. bonaczyi* appears to be identical with *A. listeri*." In 1922 Pilsbry figured the type of *B. bonaczyi* (pl. 39, figs. 1, 2), which is a true *Barbatia* and has nothing to do with *A. umbonata*.

The single specimen at hand is not encrusted by any rock material and looks like a Recent somewhat worn shell. The possibility of having been removed by any means from its original place

of deposition cannot be excluded. Another specimen from the Cumarebo area, however, shows the same state of preservation but is entirely filled with matrix of the bed from which it has been collected.

Comparisons.—*A. occidentalis* Philippi and *A. paratina* Dall have been compared with *A. umbonata* by Gardner (1926, p. 25). Sheldon (1917, p. 9) considered *A. americana* d'Orbigny (1815, p. 342; 1842, pl. 28, figs. 1, 2) as a synonym. The figures, however, show a much more prominent rib on the umbonal ridge, and the characteristic ligamental grooves of *A. umbonata* are missing. A striking resemblance to *A. umbonata* has *A. hatchetigbeeensis* Harris (1897, p. 47, pl. 7, figs. 10, 10a) from the Hatchetigbee fm., Wilcox group, lower Eocene of Alabama. Comparative remarks have been given by Sheldon (1917, p. 6), who refigured the holotype. *A. grammatodonta* Dall (1915, p. 118, pl. 20, figs. 1, 2; pl. 22, fig. 3) has been compared by Dall with *A. paratina*. But it seems to me that it is more closely related to *A. umbonata*, and the study of the type material would perhaps prove its identity with *A. umbonata* (fide Mansfield, 1937a, p. 195). *A. umbonata* has further been compared with *A. umbonata morantensis* by Woodring (1925, p. 30) and with the Recent Pacific *A. mutabilis* (G. B. Sowerby I) by Olsson (1961, p. 77).

Occurrence.—N.V.P. Blue No. 3892.

Distribution.—Gatún formation of Costa Rica; Chipola formation and Oak Grove sand of Florida; Cercado formation of the Dominican Republic; Miocene of Puerto Rico; Pliocene of St. Petersburg, Florida; Pleistocene of the Florida Keys; Quaternary of the State of Zulia, Venezuela; Recent from North Carolina through the West Indies to Brazil.

Genus **BARBATIA** Gray

Gray, 1842, Synopsis of the contents of the British Museum, ed. 44, p. 81.

Type species (by subsequent designation, Gray, 1847, Zool. Soc. London, Proc., pt. 15, p. 197), *Arca barbata* Linné.

Subgenus **CUCULLAEARCA** Conrad

Conrad, 1865, American Journal of Conchology, vol. 1, pt. 1, p. 11.

Type species (by subsequent designation, Stoliczka, 1871, *Palaeontologia Indica*, vol. 3, p. 340), *Arca cuculloides* Conrad (= *Byssosarca lima* Conrad).

Barbatia (Cucullaearca), n. sp. aff. mississippiensis (Conrad)

Pl. 51, figs. 3, 5

1847. *Byssosarca mississippiensis* Conrad, Acad. Nat. Sci. Philadelphia, Proc., vol. 3, p. 295.

Outline of shell irregular. Anterior margin oblique, extending forward, slightly curved, and forming a rounded angulation with the ventral margin. Large byssal gape on the anterior portion of the ventral margin. Posterior margin straight, extending posteriorly, evenly rounded postero-ventrally. Inner margin smooth except postero-ventrally, where a few faint crenulations are indicated. Inner surface finely striate. Hinge narrow and edentate centrally, becoming broader towards the extremities, especially posteriorly, with some large, oblique, curved or broken teeth. Edges of hinge angulated posteriorly only. Cardinal area trigonal, high, and steep, bordered by a ridge. There are about seven grooves, broken just behind the beaks. Umbones low and broad. Umbonal ridge accentuated in younger stages but rounded towards the margin. Posterior slope concave. Radial sculpture consists of numerous irregularly spaced ribs. Anteriorly they are irregularly noded and partly narrower than their interspaces. On the middle portion they are narrowest, becoming much broader towards the umbonal ridge, where they generally carry a medial sulcus. Two or three closely spaced ribs may form a group separated by a wide interspace from another similar group. Sculpture on posterior slope less distinct. Several more or less accentuated growth lines stress the irregular aspect of this species.

Remarks.—It is difficult to separate the *Cucullaearcas* from each other because characteristics as outline or sculpture are subject to extreme variability and thus only of restricted diagnostic value. Olsson (1961, p. 82) stated that "the valves are often much distorted because of its nestling habit." Maury (1922, p. 14) discussed this difficulty for the *B. reeveana*-group.

Comparisons.—Most closely related to this form is *B. mississippiensis* (Conrad). The best preserved valve (G 11263) shows

a strongly produced anterior portion, whereas on Sheldon's figures (1917, pl. 3, figs. 1-4) it is evenly rounded. On the other hand a 60 mm. long fragment (G 11317) has a short and angulated anterior margin. A constant difference is that of the position of the umbones. On these specimens they are situated more centrally. The sculpture of *B. mississippiensis* seems to be more regular than on the specimens studied. *B. inusitata* (Woodring) (1925, p. 35, pl. 3, figs. 15, 16) is less elongate. Its hinge and cardinal area have other proportions. *B. cuculloidis* (Conrad) (1833, Harris reprint, p. 59, 1893), well figured by Sheldon (1917, pl. 2, figs. 8-12), is the type species of *Cucullaearca*. The sinus of its ventral margin is less pronounced, but its umbonal ridge is more accentuated than in this material. *B. marylandica* (Conrad) (1838, p. 54, pl. 29, fig. 1) does not show the characteristic difference in height anteriorly and posteriorly. The byssal gape is not pronounced. *B. caloosahatchiensis* (Sheldon) (1917, p. 17), a new name for *B. irregularis* Dall, is similar but lacks the few, strong, and widely spaced anteriormost ribs. *B. platensis* (Philippi) (1893, p. 11, pl. 1, fig. 8) has a strong depression in the middle of the shell, and the ribs on the posterior slope are much broader than those on these specimens. *B. seymourensis* (Dall and Ochsner) (1928, p. 117, pl. 2, fig. 18, pl. 4, fig. 5) has much coarser sculpture on the umbonal ridge and only two grooves on the cardinal area.

Occurrence.—N.V.P. Blue No. 3892.

Genus **ANADARA** Gray

Gray, 1847, Zool. Soc. London, Proc., pt. 15, p. 198.

Type species (by original designation), *Arca antiquata* Linné.

Subgenus **CUNEARCA** Dall

Dall, 1898, Wagner Free Inst. Sci., Trans., vol. 3, pt. 4, p. 618.

Type species (by monotypy), *Arca incongrua* Say.

- Anadara (Cunearca) zorritensis** (Spieker) Pl. 50, figs. 16-18
 1870. *Scapharca* sp. ind. Nelson, Conn. Acad. Sci., Trans., vol. 2, pt. 1, p. 205.
 1922. *Arca (Cunearca) zorritensis* Spieker, Johns Hopkins Univ. Studies in Geol., No. 3, p. 96, pl. 5, figs. 4, 5.
 1927. *Arca (Scapharca) vuelatana* H. K. Hodson, Bull. Amer. Paleont., vol. 13, No. 49, p. 9, pl. 5, figs. 2, 4, 6.
 1927. *Arca (Scapharca) vuelatana falconensis* H. K. Hodson, *idem*, p. 9, pl. 5, figs. 5, 7, 9.

1932. *Arca* (*Cunearca*) *zorritensis* Spieker, Olsson, Bull. Amer. Paleont., vol. 19, No. 68, p. 70, pl. 4, figs. 3, 5, 11.

Shell small, about as long as high. Anterior and posterior margins rounded. Ventral margin oblique to the hinge. Only slightly produced postero-ventrally. Angles at edges of hinge not accentuated. Cardinal area narrow behind the beaks, bordered by an elevated margin, and carrying one groove. In front of the beaks broad and short. Umbo low and mesially impressed. Umbonal ridge rounded, not conspicuous. Radial sculpture consists of 23-28 ribs. On the left valve all of them are strongly noded and somewhat broader than their interspaces. Anterior ribs broader than posterior ones. Ribs of the right valve narrower than those of the left valve and smooth except the anteriormost ones.

Type.—Nelson collection, Peabody Museum, Yale University.

Remarks.—It is difficult to decide whether these specimens belong to *Cunearca* or *Scapharca*. They seem to be intermediate between the two subgenera. They show the discrepancy in sculpture of the two valves typical for *Cunearca*, but on the other hand their cardinal area is not so broad and steep as in the members of the *A. pittieri*-group which are representative for *Cunearca*.

The specimens are not identical with *A. zorritensis*. They differ in being smaller and in having the umbo mesially impressed. These differences, however, do not seem to be more than that of variation.

Olsson (1932, p. 70) placed *A. pantheonensis* (Spieker) (1922, p. 99) in the synonymy of *A. zorritensis* stating that "except in size it does not differ sufficiently in form or sculpture to be considered as a separate species."

Comparisons.—*A. ophanta* (Woodring) (1925, p. 50, pl. 5, figs. 14, 15) from Bowden, Jamaica, is more circular in outline, umbones not mesially impressed, and its ribs are rounded, whereas in *A. zorritensis* they are rectangular in cross section. *A. saladilloensis* (H. K. Hodson) in Hodson, Hodson, and Harris (1927, p. 8, pl. 5, figs. 1, 3) has more rounded ribs. If its type material would be compared with that of *A. ophanta*, it would probably prove to be synonymous with the latter, although according to the figures of the types *A. saladilloensis* is somewhat produced

postero-ventrally and has the umbones mesially impressed. *A. pomponiana* (Pilsbry and Johnson) (1917, p. 190; Pilsbry 1922, p. 407, pl. 42, figs. 4-6) from the Miocene of the Dominican Republic is less elongate than *A. zorritensis*, more rounded postero-ventrally, and its umbones are not mesially sulcate.

Occurrence.—N.V.P. Blue No. 3892.

Distribution.—Tumbes formation (upper Miocene) of Perú. Caujarao formation, Falcón, Venezuela.

Anadara (Cunearca) inutilis, n. sp

Pl. 51, figs. 1, 6-8

Shell trigonal in outline, especially in old specimens. Ventral margin about parallel to hinge. Anterior margin regularly curved. Postero-ventrally produced. Cardinal area asymmetrical, steep and concave, in front of the beaks broader, bordered on the posterior portion by a ridge. In adult specimens three—four grooves. Teeth of the posterior row mostly broken, those of the anterior row only towards its edge. Medial sulcation of umbo sometimes feebly indicated. Umbo broad and in old stages high. Umbonal ridge slightly curved outwards and more accentuated in younger stages. The area in front of the umbonal ridge somewhat concave. Number of ribs on most specimens 24. The ribs of the left valve are as a rule transversely beaded, rectangular in cross section anteriorly and medially, but rounded posteriorly. In later stages the anterior ribs are sulcate medially, *i.e.* the transverse nodes are elevated at their edges only, leaving a groove in the center. On the middle portion of the shell the ribs become broader than their interspaces, but on the posterior slope they narrow again. All the interspaces are crossed by fine concentric growth lines. Ribs of the right valve much narrower. On the anterior portion they are coarsely beaded, and mesially grooved in later stages as on the left valve. On the central part they become much narrower than their interspaces, flat-topped, and in general smooth. On the posterior slope they are slightly rounded in cross section, and carry nodes again as they approach the postero-dorsal margin. The concentric lamellae in the interspaces are even finer than those of the left valve.

Holotype.—Natural History Museum, Basel, No. G 11266.

Dimensions of holotype (left valve).—Length 17.1 mm., height 15.8 mm., diameter 8.1 mm.

Variability.—The following morphological elements are variable: Left valve. 1. Umbonal ridge sharply accentuated or more rounded. 2. Ribs in front of umbonal ridge; a) extremely broad or narrower than some of the more anterior ones; b) more or less beaded. 3. Ribs on posterior slope strongly or only weakly beaded. Right valve. 1. Umbonal ridge sharply accentuated or more rounded. 2. Ribs of the central part smooth or slightly beaded. 3. Posteriormost ribs more or less beaded.

Remarks.—Young and mature individuals are different in general appearance. The young are rhomboidal in outline, whereas the old trigonal. This is due to the fact that the ratios of the distances: Hinge—highest point of umbo, and hinge—ventral margin change rapidly in the course of growth. In a young individual the distance hinge—umbo measures 2.1 mm., and hinge—ventral margin 7.2 mm. (ratio 0.29). The greatest specimen at hand (G 11318) has the following corresponding measurements: 6.0 mm. and 15.1 mm. (ratio 0.39). *A. inutilis* may grade into other species depending on the combination of the different variable features.

Paratypes have been sent to the British Museum (Natural History), the Paleontological Research Institution, Ithaca, New York, and the U.S. National Museum, Washington, D.C.

Comparisons.—*A. inutilis* closely resembles *A. thalia* (Olsson) (1932, p. 69, pl. 2, figs. 7-9) from the lower Zorritos formation of Perú. It mainly differs by the distinct dissimilarity of sculpture on the two valves. In *A. thalia* the medial ribs of the right valve are beaded and relatively broad, whereas those of the present specimens are generally smooth and narrower. The cardinal area of *A. thalia* has one groove only. The umbones of *A. inutilis* are higher. *A. thalia* and *A. inutilis* belong to the group of *A. pittieri* (Dall) (1912, p. 9). Topotypes of *A. pittieri*, *A. lloydi*, and *A. hindsii* (all from the Gatún formation of the Banana River, Costa Rica) are at hand. *A. pittieri* is somewhat larger, has narrower ribs on the left valve, and those of the right valve are somewhat beaded on the middle portion. Its cardinal area is less asymmetrical, and its umbonal ridge generally more accentuated than in *A. inutilis*. *A. lloydi* (Olsson) (1922, p. 192, pl. 24, figs. 10-12) has more numerous and narrower ribs, lower umbones, and a less pro-

nounced umbonal ridge. The interstitial threads between the ribs just in front of the umbonal ridge of the right valve are not present in *A. inutilis*. *A. hindsii* (Olsson) (1922, p. 193, pl. 24, figs. 7-9) has a less marked umbonal ridge and wider interspaces. The three last mentioned species never show any indication of doubled ribs. *A. corcupidonis* (Maury) (1917, p. 175, pl. 30, figs. 5-7) from the Cercado formation of the Dominican Republic, has a regularly rounded umbonal ridge, the same number, but narrower ribs, and is not produced postero-ventrally. Its ventral margin is evenly rounded and oblique to the hinge. *A. hispaniolana* (Maury) (1917, p. 176, pl. 30, figs. 9, 10) is similar to *A. inutilis* in outline and sculpture, but the ribs of the right valve are not smooth. *A. filicata* (Guppy) (1866b, p. 583, pl. 26, fig. 5) has slightly more but similarly arranged ribs, a less asymmetrical cardinal area, and a more rounded umbonal ridge. Its well-rounded ventral margin is oblique to the hinge, and the angles at both edges of the hinge more conspicuous. *A. alcima* (Dall) (1898, p. 635, pl. 31, figs. 5, 7) has a more circular outline, lower umbones, and more ribs. *A. chavezii* (Engerrand and Urbina) (1910, p. 131, pl. 60, figs. 56-60, 62-65), related to *A. alcima*, has more ribs, lower umbones, and no accentuated umbonal ridge.

In addition *A. inutilis* may be compared with the Recent Caribbean *A. chemnitzii* (Philippi) and the Recent Pacific *A. nux* (G. B. Sowerby I). The former reaches a larger size, has more ribs, and the umbo less prosogyrate. *A. nux* is similar in outline but has only 22-23 ribs. According to Olsson's figures (1961, pl. 9, figs. 8, 8a) the central ribs of the right valve seem to be slightly beaded, and near the umbonal ridge interstitial threads are visible.

Occurrence. — N.V.P. Blue No. 3892.

Subgenus SCAPHARCA Gray

Gray, 1847, Zool. Soc. London, Proc., pt. 15, p. 198.

Type species (by original designation), *Arca inaequalis* Bruguière.

Anadara (Scapharca) aff. cornellana (H. K. Hodson) Pl. 52, figs. 1-4
Pl. 53, figs. 1, 2
1927. *Arca (Scapharca) cornellana* H. K. Hodson, in Hodson, Hodson, and Harris. Bull. Amer. Paleont., vol. 13, No. 49, p. 12, pl. 6, figs. 4, 5

Left valve slightly larger than right valve. Anterior margin evenly rounded, continuing without angulation into the ventral margin, which is parallel or slightly oblique to the hinge line. Posterior margin straight, ending in a sharp and extremely produced postero-ventral angulation. Angle at hinge edges more accentuated anteriorly. Cardinal area narrow behind the beaks, where it is bordered by a ridge; in front of them broader, short, and somewhat triangular; with one or two grooves, more in old specimens. Umbo low, mesially impressed. Umbonal ridge more or less accentuated, rounded. Posterior slope mostly short, steep, and slightly concave. Both valves similarly sculptured with 35-40 ribs. Ribs of left valve wider than their interspaces; those in front of the umbonal ridge larger than the others. Ribs smooth in young stages; nodes increasing in size towards margin. Nodosity restricted to anterior ribs and to ventral portion of central part of shell. Towards the umbonal ridge and on the posterior slope the ribs are nearly smooth and crossed by concentric growth lines like their interspaces. In old stages some of the anterior ribs may carry a medial sulcus. Ribs of right valve slightly narrower than those of left valve but always broader than their interspaces; noded to some degree on the anterior part but otherwise smooth.

Remarks.—The rich material at hand constantly differs from *A. cornellana* by its higher number of ribs. The holotype of *A. cornellana* has 31 ribs, whereas the average number of our material is 37. In addition the angulation at the posterior edge of the hinge often is less pronounced.

Comparisons.—*A. intumulata* (Pilsbry and Johnson) (1917, p. 187; Pilsbry, 1922, p. 404, pl. 39, figs. 7-9) from the Miocene of northern Colombia is similar to this form. It differs in being more produced postero-ventrally. Its ventral margin is oblique to the hinge instead of parallel. The posteriormost part of the hinge is slightly bent downwards in this material, whereas in *A. intumulata* it is straight. *A. wiedenmayeri* (H. K. Hodson) (*in* Hodson, Hodson, and Harris, 1927, p. 3, pl. 1, figs. 2, 6) from the State of Falcón is larger and much less elongate, and has fewer ribs. *A. acompsa* (Dall) (1898, p. 648, pl. 33, fig. 15) from the Chipola formation of Florida has the same number but much

broader ribs with narrow interspaces. Its hinge is longer posteriorly than in our material.

Occurrence.—N.V.P. Blue No. 3892, Re 1148, Re 1154, Re 1199.

Anadara (Scapharca) veatchi matarucana (H. K. Hodson)

Pl. 52, figs. 5, 6, 9

1927. *Arca (Scapharca) veatchi matarucana* H. K. Hodson in Hodson, Hodson and Harris, Bull. Amer. Paleont., vol. 13, No. 49, p. 10, pl. 3, figs. 4, 5.

Outline of shell quadrate. Anterior margin regularly rounded, forming a conspicuous angle of about 100° with the hinge line. Ventral margin straightened. Posterior margin straight or slightly curved. The posterior edge of the hinge projects as a little auricle forming an angle of about 90° with the posterior margin. There is a little concavity just ventrally to this auricle. At its deepest point the internal crenulation of the margin sets in. Hinge straight, bent ventrally at posterior extremity. Teeth more oblique, and sometimes broken, posteriorly. Cardinal area relatively narrow behind the beaks, and bordered by a ridge which is in direct connexion with the above mentioned auricle at the posterior extremity of the hinge. In front of the beaks broader and triangular. There are three grooves broken just behind the beaks. Beaks low, umbo full, but not high, and mesially sulcate. Umbonal ridge pronounced, but rounded. Radial sculpture consists of 40-43 ribs. Ribs of young stages smooth. On the left valve, which is somewhat larger than the right, the development of nodes is characteristic for the anterior ribs, and for those situated towards the central part of the shell. In front of the umbonal ridge the nodes begin to disappear, and on the steep and concave posterior slope they are entirely absent. All the ribs of left valve have a medial sulcus. On the anterior ribs these sulci are broad, but gradually narrow reaching a minimum at about the center of the shell disc, and widen again posteriorly. Interspaces, which are crossed by fine concentric growth lines, not as wide as ribs. Ribs of right valve narrower than those of left valve but still wider than or as wide as their interspaces. They are smooth except on the anterior part where they carry transverse nodes. Medial sulcus less pronounced than on left valve.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 21876.

Remarks.—The holotype, a right valve, shows several fine

grooves on the ribs around the umbonal ridge. But these grooves appear only near the margin. The holotype measures 55 mm. in length, a size never attained by these specimens. The above mentioned feature does not occur on the material of this collection except on one fragment of a right valve (G 11274) which must have reached a length of about 40 mm. Its preserved ribs on the posterior slope show two grooves. I conclude, therefore, that even the large valves of the material are not adult.

Comparisons.—*A. veatchi* (Olsson) (1922, p. 189, pl. 23, figs. 1-3) from the Gatún formation of northwestern Panamá and the Canal Zone has an almost circular outline, whereas the subspecies is slightly produced postero-ventrally causing a marginal angulation. The angles at the edges of the hinge are more pronounced in the subspecies, and its beaks seem to be lower. A related, but much larger species, is *A. hopkinsi* (Pilsbry and Olsson) (1941, p. 51, pl. 11, figs. 1, 2) from the Canoa formation (Pliocene) of western Ecuador. It has only about 38 ribs which do not carry nodes but several fine threads. It is more rounded postero-ventrally than this form and its umbonal ridge less pronounced. *A. halidonata* (Dall) (1898, p. 646, pl. 33, fig. 24) and its subspecies *oresta* (Woodring) (1925, p. 43, pl. 4, figs. 5, 6) are more elongate forms with fewer ribs. *A. columba* (Olsson) (1932, p. 67, pl. 1, figs. 2, 6) from the Cardalitos formation (middle Miocene) of Perú has been compared with *A. veatchi* by Olsson.

Occurrence.—N.V.P. Blue No. 3892.

Distribution.—Caujarao formation, Falcón, Venezuela. Hodson also recorded this species from his locality No. 2207.

Anadara (Scapharca) tirantensis (H. K. Hodson)

Pl. 52, figs. 7, 8

Pl. 53, figs. 3, 4

1927. *Arca* (*Scapharca*) *tirantensis* H. K. Hodson, in Hodson, Hodson, and Harris, Bull. Amer. Paleont., vol. 13, No. 49, p. 11, pl. 7, figs. 2, 3.

Shell heavy and elliptical in outline. Only slightly angulated at anterior end of hinge. Anterior margin regularly arcuate. Lowest point of shell only little behind the beaks. Margin continuing posteriorly up into a narrow arch, of which the posteriormost point lies about in the middle of the height of the shell. Postero-dorsal margin practically in uninterrupted continuation with the line separating the cardinal from the sculptured area. Posterior muscle

scar large. Inner surface of shell finely striate above the marginal crenulation. Hinge teeth numerous, nearly vertical except towards the posterior end. Cardinal area wide, steep, somewhat broader in front of the beaks, carrying seven—eight grooves which are bent just behind the beaks. Anterior portion of cardinal area bordered by an incised line and by an elevated margin posteriorly. Umbo sulcate mesially. Valves strongly inflated. Umbonal ridge not conspicuous and rounded. Radial sculpture consists of about 33 ribs. Anteriorly they are broader than their interspaces and mesially grooved; centrally they become narrower, flat-topped (without sulcus), their interspaces being broader; posteriorly they become dichotomous again, broader, and are finely beaded. Interspaces ornamented throughout by fine concentric lamellae, especially visible on the anterior ribs. On the central portion these lamellae are gently arched, the concave side facing dorsally. One or more concentric furrows or constrictions are the cause of a (when observed in profile) wavy outer surface. The constrictions may even have a continuation on the cardinal area manifested by a shallow longitudinal sulcus.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 21903.

Comparisons.—*A. mirandana* (H. K. Hodson) (*in* Hodson, Hodson, and Harris, 1927, p. 11, pl. 5, figs. 12, 13) has practically the same general form as *A. tirantensis* but differs by its smaller size and by having more and closer-set ribs. The original description does not mention divided ribs, but the figures show at least indications of this feature near the posterior extremity. *A. dariensis* (Brown and Pilsbry) (1911, p. 362, pl. 22, fig. 10) (= *A. gatunensis* Toulà 1911, p. 493, pl. 30, fig. 4) from the Gatún formation of the Panamá Canal Zone differs from our material in having less inflated valves, fewer ribs, and in being more elongate. According to the original figure *A. dariensis* has conspicuous angulations at the edges of the hinge, whereas the type of *A. gatunensis* has rounded edges like *A. tirantensis*. Olsson (1922, pl. 22, figs. 10-13) obviously considered that as a variable feature. *A. alargada* Marks (1951, p. 56, pl. 1, figs. 10, 11) from the Subibaja formation (lower Miocene) of southwestern Ecuador has a similar outline but is an *Andara s.str.* (equivalve), is smaller, and has fewer ribs.

A. costaricensis (Olsson) (1922, p. 186, pl. 25, figs. 1, 2) from the Gatón formation of Costa Rica is a much larger species with fewer ribs. *A. latidentata* (Dall) (1898, p. 638, pl. 32, fig. 15) from the Chipola formation of Florida is smaller, somewhat less produced posteriorly, and has fewer and undivided ribs. *A. strebla* (Gardner) (1926, p. 33, pl. 8, figs. 1, 2) from the Shoal River formation of Florida is a larger species with a conspicuous angulation at the anterior edge of the hinge. *A. propearesta* (Mansfield) (1932a, p. 52, pl. 5, figs. 2, 4, 6) from the *Arca* Zone (upper middle Miocene) and the *Cancellaria* Zone (upper Miocene) of Florida is also angulated at the antero-dorsal margin, has fewer ribs, and a less arched ventral margin. *A. istmica* Perrilliat Montoya (1960, p. 12, pl. 1, figs. 3-5) from the Isthmus of Tehuantepec is larger, angulated at the antero-dorsal margin, and all its ribs are divided. *A. collazica* (Sheldon and Maury) (Maury 1920, p. 9, pl. 1, fig. 4) from Puerto Rico has a similar shape but is more produced antero-dorsally, more elongate, and is said to have undivided ribs.

Occurrence.—N.V.P. Blue No. 3892, Re 1148, Re 1152, Re 1151.

Distribution.—Known from the State of Falcón only.

Anadara (Scapharca) cf. spiekeri (Olsson)

Pl. 53, figs. 6, 7

1932. *Arca (Diluvarca) spiekeri* Olsson, Bull. Amer. Paleont., vol. 19, No. 68, p. 65, pl. 2, figs. 2, 3, 6.

Rounded anterior margin continuing without angular interruption into ventral margin. Posterior margin somewhat straightened. Postero-ventrally produced. Angulated at both ends of hinge line. Cardinal area longer and narrow behind the beaks, broad and short in front of them, carrying three broken grooves in adult individuals. Umbo broad but low, mesially impressed. Umbonal ridge more or less accentuated. Radial sculpture consists of 33-36 ribs. On the left valve these are about as wide as their interspaces, noded throughout, but more intensively on the anterior half of the shell. Interspaces ornamented by fine concentric growth lines. Ribs of right valve narrower than their interspaces, flat-topped, and smooth except the anteriormost ones, which are transversely noded. Their broad interspaces are crossed by fine concentric lamellae.

Variability.—The general appearance is influenced by the

variable accentuation of the umbonal ridge. In younger stages it is generally sharpened to some degree but rounded towards the postero-ventral extremity. The anterior ribs of the right valve may be broader or as wide as the posterior ones but are always more or less noded.

Remarks.—The subgeneric assignment of this form is questionable. The sculpture is that of a *Cuncarca*, but the cardinal area that of a *Scapharca* (*vide* Reinhart, 1935, pp. 61-62.)

Comparisons.—This form seems to be intermediate between *A. spiekeri* and *A. sechurana*. *A. spiekeri* has fewer ribs and a distinct shallow inflexion in front of the umbonal ridge which is indicated on some of the specimens but not always present. Its ribs of the right valve are somewhat beaded near the ventral margin and on the posterior slope. Olsson compared his *A. spiekeri* with *A. singewaldi* (Spieker). From *A. sechurana* (Olsson) (1932, p. 67, pl. 4, fig. 1) the specimens differ in size. The number of ribs is the same, but they are less noded. According to the original description the valves are similarly sculptured, a feature not present in the present form. *A. tolepi*a (Dall) (1898, p. 649, pl. 33, figs. 7, 8) has higher beaks and is more circular in outline [compare Woodring's (1925, p. 49) synonymy and remarks under his *Barbatia microtera*]. *A. tolepi*a *scapularis* (Pilsbry and Johnson) (1917, p. 189; Pilsbry 1922, p. 407, pl. 39, figs. 13, 14) stands close to the present form, but its 33 ribs seem to be less noded and have narrower interspaces. There is no shallow sulcus anterior to the umbonal ridge. *A. proletaria* (Pilsbry and Johnson) (1917, p. 188; Pilsbry, 1922, p. 404, pl. 39, figs. 5, 6) shows the same differences to the specimens studied as *A. tolepi*a *scapularis*, except that it is slightly more elongate than the latter. *A. zuliana* and *A. zuliana maracaibensis* (H. K. Hodson) (*in* Hodson, Hodson, and Harris, 1927, pp. 4-5) have more ribs and a broader cardinal area. *A. weeksi* (H. K. Hodson) (*in* Hodson, Hodson, and Harris, 1927, p. 5, pl. 4, figs. 4, 6) has fewer ribs and is less produced postero-ventrally.

Occurrence.—N.V.P. Blue No. 3892, Re 1148, Re 1199.

Genus **NOETIA** Gray

Gray. 1857, Ann. Mag. Nat. Hist., ser. 2, vol. 19, p. 371.

Type species (by monotypy), *Noetia triangularis* Gray (= *Arca reversa* G. B. Sowerby I).

***Noetia dauleana paraguayensis*, n. subsp.**

Pl. 53, figs. 5, 10, 11

Outline of shell subrhomboidal. Anterior margin regularly rounded, posterior and ventral margins nearly straight forming a pronounced angulation postero-ventrally. Inner margin strongly crenulated. Hinge divided into two parts forming together a slight angle. The longer anterior part is broadest below the anterior edge of the ligamental area and narrows progressively towards both sides. The posterior shorter part has slightly curved teeth towards the outer edge but not angulated ones as on the anterior part. Ligamental area steep and situated mainly in front of the beaks, only a small portion reaching somewhat posteriorly to them. Umbonal carination curved, its convex side facing anteriorly. The region in front of it tends to be radially impressed. Radial sculpture consists of 32-36 ribs; 10-12 of them situated on the posterior slope. While slightly rounded on the posterior slope and the posterior part of the main shell disc, they become flattened and broader anteriorly. A few concentric and coarse growth lines divide the shell into several unequal portions. The growth lines converge behind the ligamental area and form an area of conspicuous parallel longitudinal grooves. There are no secondary radial riblets.

Holotype.—Basel Natural History Museum, No. G 11286.

Dimensions of holotype (left valve).—Length 30.1 mm., height 26.6 mm., convexity 13.3 mm.

Remarks.—The material consists of the holotype and 11 paratypes. A small right valve (G 11288) (length 14.7 mm., height 12.9 mm., convexity 5.5 mm.) from locality 3892 shows close affinity to the above described form. It differs from it in the following characters: the umbo is slightly lower, the margin just above the posterior edge of the hinge is somewhat angulated, and the angle between the two rows of teeth is less pronounced. The postero-ventral angulation is less conspicuous, a feature, however, that generally develops in later stages only. Whether this specimen must be regarded as a young of *N. dauleana paraguayensis*, or as a different form, is questionable.

Paratypes have been sent to the British Museum (Natural History), the Paleontological Research Institution, Ithaca, New York, and the U.S. National Museum, Washington, D.C.

Comparisons.—The main differences between *N. dauleana paraguanensis* and *N. dauleana* Marks (1951, p. 52, pl. 1, figs. 7-9) from the Daule formation (middle Miocene) of southwestern Ecuador are as follows: the subspecies does not show any secondary ornamentation which is present in *N. dauleana* on the posterior slope and just in front of the umbonal carination. The ligamental area of corresponding-sized specimens seems to be broader in the subspecies, and the number of teeth on both parts of the hinge is higher in *N. dauleana*. The umbo of *N. colombiana* MacNeil (1938, p. 34, pl. 5, figs. 10, 11) from the middle Miocene of northern Colombia is lower and situated much closer to the posterior edge of the hinge. The two parts of the hinge are much more unequal, and the ligament becomes wider anterior to the beaks, whereas in *N. dauleana paraguanensis* it is broadest below the beaks, and narrows slowly towards its anterior end. *N. ecuadoria* MacNeil (1938, p. 33, pl. 5, figs. 12, 13, 20) from the lower middle Miocene of Ecuador carries secondary riblets. Beaks and umbones are lower than in *N. dauleana paraguanensis*. The anterior row of teeth in *N. retractata* (Hanna and Israelsky) (1925, p. 61) (= *N. modesta* Grzybowski from the Zorritos formation of Perú is decidedly curved or even angulated. The nearly quadrate outline is in contrast to the produced postero-ventral part of *N. dauleana paraguanensis*. Seven specimens of *N. macdonaldi* (Dall) (1912, p. 9) from the Gatún formation of Banana River, Costa Rica, are at hand. Some of them represent the subspecies *alta* MacNeil (1938, p. 36, pl. 6, figs. 1, 2, 8, 9). The typical form of *N. macdonaldi* is somewhat larger than *N. dauleana paraguanensis*, and its shell is heavier. Its umbonal ridge is sharper, the posterior slope more concave, and there may be a few faint interstitial threads on the posterior slope. The posterior margin is straight, whereas in the form from Paraguaná it is somewhat curved. The Recent Pacific *N. reversa* (G. B. Sowerby I) (1833, p. 20), of which one shell is at hand, is slightly smaller, carries interstitial threads on the posterior slope, and has a steeper posterior mar-

gin. Its ligament, which is narrower than that of *N. dauleana paraguayensis*, lies wholly anteriorly.

Occurrence.—N.V.P. Blue No. 3892, Re 1152, Re 1155.

Genus **EONTIA** MacNeil

MacNeil, 1938, U.S. Geol. Sur., Prof. Paper 189-A, p. 11.

Type species (by original designation), *Arca ponderosa* Say.

Eontia, n. sp. aff. **centrota** (Guppy)

Pl. 53, figs. 8, 9

Remarks.—I have a single left valve of a species that seems to be related to *Eontia centrota* (Guppy). The pattern of sculpture given in the original description (Guppy, 1867, p. 175; reprint, Harris, 1921, p. 54) agrees well with the specimen. There are 37 strongly beaded radial ribs, anteriorly and especially posteriorly with fine intercalated riblets. Postero-ventrally the main ribs tend to double. Anterior and posterior margins rounded, somewhat angulated at the anterior edge of the hinge line. The umbonal ridge is pronounced in young stages only, flattening towards the margin. On the first figures given by Guppy (1873b, pl. 3, figs. 4a, 4b; reprint, Harris 1921, pl. 1, figs. 4a, 4b) the umbo is situated a little in front of the middle of the hinge, whereas the beak of this specimen lies in its first third. MacNeil (1938, p. 13) put these figures in the synonymy of *E. bisulcata* (Lamarck), stating that Guppy's figure of 1874 (pl. 18, fig. 23) was prepared for the 1867 paper but not issued with it. The latter figure, however, shows a sculpture differing from the original description. There are less than 30 broad, closely spaced, beaded ribs. A strong angle at the posterior end of the hinge and an accentuated umbonal ridge are features not present on the first figure. As stated by Maury (1925, p. 38) the ligamental area is small, the transverse grooves being restricted to the portion anterior to the beaks. MacNeil's description and figures (1938, p. 12, pl. 1, figs. 11, 12) agree well with the present valve. The postero-ventral margin of the specimen is not angulated (a feature perhaps indicating its juvenile state) and the typical number of ribs (33 or 34) pointed out by MacNeil is in contradiction to Guppy's original statement (36-38) and contrary to what is shown by this specimen.

A large number of specimens of *E. centrota* from its type locality, the Matura Bay, Trinidad (compare Rutsch, 1942, p. 110), is at hand. Adult specimens are highly produced and somewhat angulated postero-ventrally, the umbo is situated on the anterior third of the hinge, and the number of ribs varies between 32 and 38. The ribs are decidedly doubled postero-ventrally, and the beads of the ribs more accentuated and closer-set on the anteriormost ones. The Matura specimens attain a larger size than does the present valve.

Occurrence. — N.V.P. Blue No. 3892.

Family GLYCYMERIDAE

Genus GLYCYMERIS da Costa

Da Costa, 1778, *Historia Naturalis Testaceorum Britanniae*, or the *British Conchology*, p. 163.

Type species (by tautonymy), *Glycymeris orbicularis* da Costa (= *Arca glycymeris* Linné).

Subgenus GLYCYMERIS s. str.

Glycymeris (Glycymeris) aff. democraciana F. and H. Hodson

Pl. 54, figs. 2, 5, 6

1927. *Glycymeris canalis democraciana* F. and H. Hodson, in Hodson, Hodson, and Harris, *Bull. Amer. Paleont.*, vol. 13, No. 49, p. 17, pl. 2, figs. 2, 5; pl. 3, fig. 2.

Shell of medium size, equilateral. Beaks weakly opisthogyrate. Number of teeth 10 or 11 on each side of the umbones. Radial sculpture consists of about 25 ribs which have a different shape on different parts of the shell. In young stages they are uniform in shape, but slightly narrower posteriorly and anteriorly. Their interspaces are crossed by fine concentric threads. In later stages a slight depression appears on several ribs of the middle portion of the shell which develops into a conspicuous groove near the ventral margin. This groove divides the rib into two unequal parts, the narrower one lying posteriorly. A second groove may be developed giving a tripartite aspect. On the antero-ventral part of the shell the ribs may be divided into four riblets by three more or less prominent grooves, whereas on the posterior part the ribs mostly remain simple.

Remarks. — The material consists of six single valves and a double-valved specimen. These shells are smaller than those de-

scribed by Hodson and Hodson as *G. canalis democraciana*. They especially differ from the holotype which is remarkably produced posteriorly. The figured paratype, however, is not produced posteriorly and shows the same sculptural pattern as the present specimens. It is possible that the shells figured by Hodson and Hodson do not represent the same species.

Comparisons.—There is a number of equilateral species with divided radial ribs and almost circular outline. *G. usiacurii* Anderson (1929, p. 153, pl. 22, figs. 3, 4) from the Tuber group of the Colombian Miocene has only about 15 flat-topped ribs alternating with a smaller secondary rib. *G. trilobcosta* Pilsbry and Brown (1917, p. 39, pl. 6, fig. 5) has more ribs than the present form. They are more elevated, at least according to Maury's figure (1925, pl. 18, fig. 11), and each of them is flanked on both sides by a secondary riblet. Young specimens of *G. schencki* Nicol (1947, p. 349, pl. 50, figs. 1-6) from the Gatún formation of the Panamá Canal Zone are similar to this form in outline and sculpture. *G. schencki* has less inflated valves, and adult individuals are somewhat produced posteriorly, whereas even the present largest specimen (length 28.5 mm.) is subcircular in outline. *G. lloyd-smithi striatidentata* Nicol (1945, p. 624), a new name for *G. lloyd-smithi multicostata* Weisbord (1929, p. 10, pl. 2, figs. 1, 2), has been compared with *G. democraciana* by Weisbord and Nicol. This comparison may be correct for the holotype but probably not for the figured paratype.

Occurrence.—N.V.P. Blue No. 3892.

Glycymeris (Glycymeris) aff. jamaicensis Dall Pl. 54, figs. 1, 3, 4

1898. *Glycymeris jamaicensis* Dall, Wagner Free Inst. Sci. Philadelphia, Trans., vol. 3, pt. 4, p. 608.

Remarks.—This species has been redescribed by Woodring (1925, p. 24, pl. 2, figs. 1-3). Several young and one adult specimen from Bowden, Jamaica, are at hand. They have the same external sculpture as the two shells from Paraguaná but the broadly rounded posterior keel typical for the Bowden material is completely lacking on the Paraguaná shells. In addition the Bowden material differs by its longer dorsal margin, the greater number of teeth, and the less circular outline.

Olsson (1922, p. 178, pl. 19, figs. 3, 4) reported this species from the Gatún formation of Costa Rica. There are three specimens from Old Man Sam Creek, Costa Rica, at hand. The largest specimen (G 11319) measures 60 mm. in height. The remaining two valves are also much larger than the Bowden shells. The posterior angulation is less accentuated than in the Bowden material.

G. tumefacta lavelensis F. Hodson (in Hodson, Hodson, and Harris, 1927, p. 17, pl. 8, figs. 1, 4, pl. 9, fig. 1) from the "Miocene" of Falcón, Venezuela, is similar to the large Costa Rican shells of *G. jamaicensis*. The holotype locality of *G. lavelensis* lies in the La Vela area, from where rich material is at hand. *G. lavelensis* constantly differs from the Costa Rican shells by a number (about 15) of more prominent radials in the young stages of the shell and by the more accentuated concentric threads. The posterior angulation of the shell is variable in strength to some degree in both species.

Occurrence.—N.V.P. Blue No. 3892.

Family PINNIDAE

Genus ATRINA Gray

Gray, 1847, Zool. Soc. London, Proc., pt. 15, p. 199.

Type species (by original designation), *Pinna nigra* Chemnitz.

Atrina spec. ind.

Remarks.—This genus is represented by two fragments (G 11297/1-2), insufficient to be determined specifically. Dorsally they are ornamented by longitudinal ribs, about equally spaced, with smooth interspaces. Ventrally there are oblique waves, widely spaced, and converging in the direction of the anterior end. The two types of sculpture may be separated by a small unsculptured area, or the oblique waves may continue up to the longitudinal sculpture, and influence the regularity of the lowest ribs.

The fragments resemble the figure given by Woodring (1925, pl. 6, fig. 9). They also carry superimposed ribs on the oblique waves.

Occurrence.—N.V.P. Blue No. 3892.

Family SPONDYLIDAE

Genus SPONDYLUS Linné

Linné, 1758, Systema Naturae, ed. 10, p. 690.

Type species (by subsequent designation, Gray, 1847, Zool.

Soc. London, Proc., pt. 15, p. 201), *Spondylus gaederopus* Linné.

***Spondylus* aff. *lucasi* Maury**

Pl. 55, figs. 2, 3

1920. *Spondylus lucasi* Maury, New York Acad. Sci., Sci. Sur. Porto Rico, vol. 3, pt. 1, p. 23, pl. 5, fig. 1.

Shell large and heavy. Anterior auricle forming an angle of about 90° , posterior one of about 120° . Ligamental area triangular, but low. Umbo little elevated over the ligamental area. Prodissoconch smooth. Hinge line straight. The two teeth are strong. Groove of inner ligament somewhat curved. The finely crenulated inner margin is evenly rounded and slightly produced postero-ventrally. Adductor muscle scar reniform. Radial sculpture consists of primary, secondary, and tertiary ribs. The primaries carry widely spaced spines. The distinction of three categories of ribs possible in young stages only. Between two primaries there is one secondary, and between a primary and a secondary there is one and later two or more tertiary ribs. In later stages the secondaries attain the size of primaries but do not carry spines or only little ones. There are no radial ribs on the auricles but many fine concentric lamellae. On the shell disc these lamellae are best visible in the interspaces of the radial ribs.

Remarks.—Only two left valves (a large (G 11298) and an immature one (G 11299)) of this form are at hand. The outer surface of the large specimen is encrusted by different organisms, so that sculptural details are difficult to recognize. The young specimen still shows a byssal notch (see Palmer, 1938, p. 5).

S. lucasi has more radial ribs between the primaries than these specimens, but otherwise the sculpture is similar. The primaries never attain a great coarseness. Maury's holotype (height 33 mm.) is much smaller than the large shell at hand (height 78 mm.). It is possible, however, that her specimen is immature.

Comparisons.—*S. falconensis* Harris (*in* Hodson, Hodson, and Harris, 1927, p. 40, pl. 23, figs. 4, 5; pl. 24, fig. 9) from the Caujarao formation of the State of Falcón is less inequilateral and has much more prominent primary ribs. The sculptural pattern of *S. filiaris* Dall (1916, p. 493, pl. 83, figs. 5, 6) is similar, but there are more ribs between the primaries, and the ribs are smooth without spines. A single left valve of *S. bostrychites* Guppy (1867, p.

176; reprint, Harris, 1921, p. 55) from Bowden, Jamaica, is at hand. The figures given by Woodring (1925), Palmer (1938), and others indicate that *S. bostrychites* is less inequilateral in outline (although this is a variable feature). The sculpture of the form from Paraguaná is much finer, and consequently there are more radial ribs.

Occurrence.—N.V.P. Blue No. 3892.

Family PLICATULIDAE

Genus PLICATULA Lamarck

Lamarck, 1801, *Système des animaux sans vertèbres*, p. 132.

Type species (by subsequent designation, Gray, 1847, *Zool. Soc. London, Proc.*, pt. 15, p. 201), *Spondylus plicatus* Linné.

Plicatula cf. *guppyi* Woodring

Pl. 54, figs. 7, 8

1925. *Plicatula guppyi* Woodring, Carnegie Inst. Wash., Pub. No. 366, p. 78, pl. 9, figs. 9-11. See also the synonym *P. vexillata* Guppy.

Remarks.—A single flat left valve is present in the collection. It has a regularly oval outline. There are five strong and high plicae, and two or three minor lateral folds. In young stages the outer surface has no plicae and is irregular. Towards the ventral margin several conspicuous growth lines give a foliaceous appearance. Resilifer pit somewhat triangular. Teeth narrow but conspicuous. Adductor scar situated posteriorly, oval in outline, very prominent, and elevated over the inner surface.

Comparisons.—When Woodring compared *P. guppyi* with *P. densata* Conrad, he stated that *P. guppyi* "is smaller than *P. densata*, has more distinctly foliaceous ribs and no secondary marginal ribs." The present valve is larger than those of Woodring's specimens. One of the folds shows the beginning of a dichotomy near the margin. Thus the shell seems to be intermediate between *P. densata* and *P. guppyi*. In any case my determination must remain questionable. *P. marginata* Say (1824, p. 136, pl. 9, fig. 4) has, judging from figures, more rounded folds and is larger than *P. guppyi*. The Pleistocene and Recent *P. gibbosa* Lamarck has less conspicuous growth lines and the folds are less accentuated. The Eocene forms *P. lalajensis* Gardner (1945, p. 70, pl. 5, fig. 4) and *P. euplecta* Gardner (1945, p. 71, pl. 1, figs.

13, 14) mainly differ in having more radial plicae.

Occurrence.—N.V.P. Blue No. 3892.

Family **OSTREIDAE**

Genus **OSTREA** Linné

Linné, 1758, *Systema Naturae*, ed. 10, p. 696.

Type species (by subsequent designation, Gray, 1847, *Zool. Soc. London, Proc.*, pt. 15, p. 201), *Ostrea edulis* Linné.

Ostrea cf. portoricoensis Hubbard

Pl. 55, figs. 1, 4

1920. *Ostrea sellaeformis portoricoensis* Hubbard, *New York Acad. Sci., Sci. Sur. Porto Rico*, vol. 3, pt. 2, p. 101, pl. 13, figs. 4, 5, 6.

Lower valve larger than upper valve with many plicae. All these plicae converge towards the upper part of a medial fold. Near the margin they may be dichotomous. Raised growth lines give an imbricated aspect. Resilifer relatively deep, straight, or curved. On both sides of it there is a furrow with a small number of pits. Adductor scar situated slightly posteriorly, shaped like a curved pear. Upper valve flat or somewhat convex, with straight or curved beaks. Sculpture consists of faint concentric lamellae. Resilifer shorter than in lower valve. On both sides of it numerous faint crenulations reach down to about the upper extremity of the muscle scar. Adductor scar as on lower valve but even more pointed.

Comparisons.—*O. democraciana* F. Hodson (*in* Hodson, Hodson, and Harris, 1927, p. 19, pl. 9, figs. 3, 7; pl. 10, figs. 1, 3) and its subspecies *O. cujiensis* (*idem*, p. 20, pl. 12, figs. 1, 2, 3) are probably synonymous with *O. portoricoensis*. *O. democraciana chiriguarana* F. Hodson (*idem*, p. 20, pl. 10, fig. 5; pl. 11, figs. 1-3) has only a few coarse and broad folds. Hodson stated that the margins of both valves are undulated (a characteristic feature of *Alectryonia*), but in the same description he said: "The upper valve may or may not be plicate." *O. berkeyi* Maury (1920, p. 14, pl. 1, fig. 6) seems to be related to the present form, but in this material the medial fold is much less accentuated and not straight as shown by the figure of the holotype. *O. buski* Woods (1922, p. 65, pl. 2, figs. 3,4) has less folds, a larger and nearly circular muscle scar, and there are more inner marginal crenulations anterior and posterior to the ligamental area.

Occurrence.—N.V.P. Blue No. 3892, Re 1193.

***Ostrea* aff. *aguaclarensis paraguaneis* F. Hodson**

1931. *Ostrea aguaclarensis paraguaneis* F. Hodson, in Hodson and Hodson, Bull. Amer. Paleont., vol. 16, No. 60, p. 5, pl. 4, fig. 2; pl. 5, fig. 2.

Remarks.—The material consists of two left valves (G 11303/1-2) only. They are almost circular in outline. Their outer surfaces are mostly encrusted by oyster fragments or corroded. One of the specimens shows a few coarse plicae in cross section. The muscle scar is large, nearly circular, and placed slightly anteriorly. The ligamental area is rectangular in outline, whereas in *O. aguaclarensis paraguaneis* it is triangular. There is a weak marginal crenulation near the ligamental area.

The specimens differ from *O. tamiamiensis* Mansfield (1932b, p. 46, pl. 14, figs. 1, 3) in having less folds and in lacking the marginal fluting. Its ligamental area is narrower, and the muscle scar is situated posteriorly instead of anteriorly to the center.

Occurrence.—N.V.P. Blue No. 3892.

***Ostrea* sp. ind. aff. *vaughani insularis* Pilsbry and Brown**

1917. *Ostrea vaughani insularis* Pilsbry and Brown, Acad. Nat. Sci. Philadelphia, Proc., vol. 69, p. 40, pl. 6, figs. 1, 1a.

Remarks.—There is a single upper valve (G 11304), the outer surface of which is partly heavily corroded, partly encrusted. Only on a few spots the faint concentric lamellae are visible. The ligamental area is broad and not deepened. On the upper part of the posterior margin there are indications of sparse crenulation. The muscle scar is large, pear-shaped, and situated centrally to somewhat anteriorly. Height of valve 96 mm.

Occurrence.—N.V.P. Blue No. 3892.

Family CRASSATELLIDAE

Genus EUCRASSATELLA Iredale

Iredale, 1924, Linnean Soc. New South Wales, Proc., vol. 49, p. 202.

Type species (by original designation), *Crassatella kingicola* Lamarck.

***Eucrassatella trinitaria venezuelana* (F. Hodson)**

Pl. 55, fig. 5

Pl. 56, figs. 1, 2

1927. *Crassatellites trinitarius venezuelanus* F. Hodson, in Hodson, Hodson, and Harris, Bull. Amer. Paleont., vol. 13, No. 49, p. 45, pl. 28, figs. 2, 6, 9.
? 1960. *Crassatella (Eucrassatella) trinitaria venezuelana* (F. Hodson), Barrios, Boletín Geol., vol. 6, Nos. 1-3, Informe No. 1082, p. 245, pl. 5, figs. 1, 2.

Shell of medium to large size. Umbones flattened. Antero-dorsal margin slightly concave. Anterior margin regularly rounded. Posterior side produced. Postero-ventral margin straight or slightly concave. Posterior extremity truncated. Anterior part of shell well inflated, followed posteriorly by a more or less accentuated concavity which is bordered by a moderately prominent umbonal ridge. Sculpture consists dorsally of a few wide waves towards the ventral margin of smaller concentric ridges which are most conspicuous on the anterior portion of the shell. Escutcheon narrower but nearly twice as long as lunule. Right hinge consists of three cardinals. Anterior two cardinals strong, long, and narrow. Posterior cardinal rudimentary, branching off from the central portion of the middle cardinal. There is no posterior but a weak anterior lateral tooth. Hinge of left valve composed of two strong cardinals which are fused together dorsally. In addition there are two laterals: posterior one long and narrow; anterior one much shorter. Muscle scars deeply impressed.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 21999.

Remarks.—There are three single valves, one of which is immature (G 11320). They have the tendency to be somewhat more inflated anteriorly than Hodson's figured specimens but otherwise seem to be identical. The specimens from Colombia reported by Barrios show the characteristic broad and deep lunule, but her figures are not clear enough to allow a detailed comparison.

Comparisons.—There are several topotypes of *E. trinitaria* (Maury) (1925, p. 175, pl. 31, figs. 1, 7) at hand. It is a more slender species, *i.e.* it is less inflated and not of the somewhat stout aspect anteriorly. The anterior margin is slightly produced in *E. trinitaria*, whereas in the subspecies *E. venezuelana* it is evenly rounded. In addition there are the differences indicated by Hodson. *E. berryi* (Spieker) (1922, p. 131, pl. 7, figs. 9, 10) from the lower Miocene of Perú is similar in general outline but differs by its more prominent umbonal ridge and concentric sculpture. Olsson (1932, p. 86) doubted Anderson's (1929, p. 159) record of this species from the middle Miocene of Colombia, suspecting the shells might belong to *E. trinitaria venezuelana*, but Marks (1951, p. 63), who has seen Anderson's specimens, confirmed their correct identification.

Occurrence.—N.V.P. Blue No. 3892.

Distribution.—Caujarao formation of Falcón, Venezuela. Miocene of Atlantico, Colombia ? (Barrios).

Family **CARDITIDAE**

Genus **CARDITA** Bruguière

Bruguière, 1792, *Encycl. Méth.*, vol. 1, pt. 2, p. 401.

Type species (by subsequent designation, Children, 1823, *Quart. Jour. Sci., Lit., Arts*, vol. 14, p. 316), *Cardita sulcata* Bruguière (= *Chama antiquata* Linné).

Cardita paraguayensis (F. Hodson)

Pl. 56, figs. 3-6

1931. *Venericardia paraguayensis* F. Hodson, in Hodson and Hodson, *Bull. Amer. Paleont.*, vol. 16, No. 60, p. 6, pl. 9, figs. 2, 3.

Shell suborbicular. Anterior and posterior margins evenly rounded, ventral margin somewhat straightened in adult specimens but also regularly arched in juvenile individuals. Sculpture of outer surface projecting over the inner margin which is coarsely crenulated. Hinge of right valve consists of two cardinals. The anterior one, which is fused to the hinge plate, is strong especially anteriorly, the posterior one rather narrow and elongate. The dorsal surface of the anterior cardinal is finely crenulated. There are one anterior and one posterior lateral teeth but only feebly indicated. Ligamental area small and elongate. Lunule small bordered by a sharp incised line. Anteriorly it curves down abruptly forming an angle of about 90° with the antero-dorsal margin of the shell. Hinge of left valve composed of two cardinals and vestigial laterals. The anterior cardinal is small and pointed fitting in a deep socket in front of the right cardinal. The posterior cardinal is narrow and elongate. Anterior muscle scar oval, posterior one more rounded. External sculpture consists of about 19 prominently noded radial ribs with wide and deep interspaces. Nodes sometimes broader than top of ribs. Mainly on the central portion of the shell the ribs carry on either side more or less accentuated auxiliary threads which appear already in young stages. On the anterior and posterior extremity they are not present. A concave area extends from the beaks to the postero-ventral margin, in which lie one or two ribs. These are less noded.

The interspaces, widest anteriorly, are slightly narrower on the posterior slope. They are crossed by concentric growth lines which are more conspicuous on the posterior third of the shell.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 24145.

Remarks.—The material consists of seven right and two left valves of several growth stages. The largest specimen (G 11321) measures 36.3 mm. in length and 35.1 mm. in height. Measurements of smallest individual (G 11310): length 14.0 mm., height 13.2 mm. Hodson put his specimens in *Venericardia*, but the hinge analysis by Verástegui (1953, p. 12, chart 2), and Gardner and Bowles' remarks on *Venericardia* and *Cardita* (1939, p. 167) make it clear that these forms belong to *Cardita*.

Comparisons.—Closely related to this form is the Bowden species *C. scabricostata* Guppy (1866a, p. 293, pl. 18, fig. 10), which, according to Woodring (1928, p. 48, footnote), is the same as Hodson's "*Venericardia*" *bowdenensis* (in Hodson, Hodson, and Harris, 1927, p. 49, pl. 29, figs. 6, 9). This species is smaller and the lunule is not strongly bent down. "*Venericardia*" *islahispaniolae* Maury (1917, p. 198, pl. 33, fig. 2) from the Gurabo formation of the Dominican Republic has been compared with *C. scabricostata* by Woodring (1925, p. 100). It differs from *C. paraguayensis* in having more ribs and indistinct lateral threads. "*V.*" *cerro-gordensis* Maury (1917, p. 199, pl. 33, fig. 3) has less ribs and is smaller. The arrangement of its secondary riblets is also different. "*V.*" *rabelli* Maury (1920, p. 29, pl. 6, fig. 7) and "*V.*" *juncalensis* Maury (*idem*, pl. 6, fig. 5) from Puerto Rico have the same sculptural pattern as *C. paraguayensis*. The hinge of "*V.*" *rabelli* is not known, and its ratio of length to height different. The number of ribs in "*V.*" *juncalensis* is much smaller (14). *C. trinidadensis* (Maury) (1925, p. 171, pl. 30, fig. 6) is closely related but has less conspicuous secondary riblets and nodes. Its ribs are more flat-topped. *C. serricosta* Heilprin (1887, p. 117, pl. 16, fig. 64) has less ribs and a straightened ventral margin, but the hinge figured by Dall (1900, pl. 38, fig. 9) is identical with that of *C. paraguayensis*. "*V.*" *zuliana* F. Hodson (in Hodson, Hodson, and Harris, 1927, p. 46, pl. 28, figs. 1, 3, 5, 11) and its two subspecies "*V.*" *maracaibensis* and "*V.*" *weeksii*, all from the Miocene of Vene-

zuela, are smaller and lack the auxiliary riblets on either side of the main radial ribs. They seem to have less ribs. "*V.*" *dominica* Weisbord (1929, p. 17, pl. 2, fig. 12; pl. 3, figs. 10, 11) lacks the lateral riblets and has less conspicuous but closer-set nodes.

Occurrence. — N.V.P. Blue No. 3892.

Distribution. — Known from type locality only.

Family **CHAMIDAE**

Genus **CHAMA** Linné

Linné, 1758, *Systema Naturae*, ed. 10, p. 691.

Type species (by subsequent designation, Schumacher, 1817, *Essai d'un nouveau système des habitations des vers testacés*, p. 123), *Chama gryphoides* Linné.

Chama aff. **berjadinensis** F. Hodson

Pl. 56, figs. 9, 10

1927. *Chama berjadinensis* F. Hodson, in Hodson, Hodson, and Harris, *Bull. Amer. Paleont.*, vol. 13, No. 49, p. 51, pl. 30, figs. 4, 8, 10, pl. 31, figs. 2, 3, 5.

Attached left valve deep, right valve only slightly concave. Attachment area large occupying the anterior half of the shell. Concentric element of the sculpture predominant over radial element. Concentric lamellae imbricated, especially near border line of attachment area. Radial riblets on lamellae distinct in younger stages but disappear towards the ventral margin. Umbo strongly twisted forward in left valve. Left cardinal crenulated dorsally. Lateral tooth with medial impression. The inner margin carries fine crenulations. Anterior adductor muscle scar reniform and larger than posterior one. Sculpture of left valve consists of irregular concentric lamellae, sometimes with obscurely indicated radial elements.

Remarks. — The material consists of two left and one right valves. The prodissoconchs of the left valves (G 11312/1-2) are hidden by the coarsely encrusted attachment area. That of the right valve is not well preserved.

The specimens principally differ from *C. berjadinensis* by the much larger attachment area and by the predominantly concentric sculpture. *C. berjadinensis* has a conspicuous radial sculpture irregularly interrupted by growth lines. Other features, however, are similar: the strongly curved umbo of the right valve; the hinge; and the crenulation of the inner margin.

Comparisons. — Wherever mentioned, *C. involuta* Guppy (1873a, p. 86, pl. 2, fig. 5; reprint, Harris 1921, p. 70) is de-

scribed as a small species. The material studied is considerably larger and has a less finely developed sculpture. Hubbard (1920, p. 109) mentioned large specimens (52 mm. in height) of *C. involuta* from the Quebradillos limestone of Puerto Rico. However, he does not distinguish *Chama* from *Pseudochama* ("... it attaches by either valve"). *C. macerophylla* Gmelin (1790, Systema Naturae, ed. 13, vol. 1, p. 3304) has much more prominent growth lines and the tendency to develop conspicuous spines. *C. congregata* Conrad (1833, p. 341) has been compared with *C. macerophylla* by Pilsbry and McGinty (1938, p. 75). It differs from this material chiefly by its more developed sculpture and its smaller size. *C. caimitica* Maury (1917, p. 199, pl. 33, fig. 7) and *C. congregatoides* Maury (1917, p. 200, pl. 33, fig. 8) from the upper Cercado formation of the Dominican Republic seem to be somewhat related to these specimens (*e.g.* they both have a crenulated inner margin), but the original figures are too poor to allow a comparison.

Occurrence.—N.V.P. Blue No. 3892.

Genus **PSEUDOCHAMA** Odhner

Odhner, 1917, Kungl. Svenska Vetenskaps-akademiens Handlingar, vol. 52, No. 16, pp. 28-31.

Type species (by subsequent designation, Gardner, 1926, U.S. Geol. Sur., Prof. Paper 142-B, p. 92), *Chama cristella* Lamarck (*vide* Nicol, 1952a, p. 248).

Pseudochama quirosana (F. Hodson)

Pl. 56, figs. 7, 8

1927. *Chama quirosana* F. Hodson, *in* Hodson, Hodson, and Harris, Bull. Amer. Paleont., vol. 13, No. 49, p. 50, pl. 30, figs. 1, 2, 5, 7.

1952. *Pseudochama quirosana* (F. Hodson), Nicol, Jour. Paleont., vol. 26, No. 5, p. 814.

Shell not constant in outline, depending on the substratum to which the shell has been attached. The attachment area comprises the anterior half of the (right) valve. The posterior half is sculptured by concentric lamellae carrying more or less conspicuous radial riblets. At the border line of the attachment area these lamellae may be set off. The right cardinal tooth is divided into two parts by a deep furrow. The anterior part is larger and carries irregular crenulations. The lateral tooth is covered by numerous irregularly set knobs. On the dorsal part of the main

groove of the hinge there are also some of these knobs. The ligamental furrow is deep and long, arched in analogy with the curvature of the umbo. The inner margin does not show any crenulations. Anterior muscle scar larger than posterior one. Outer surface of left valve coarsely lamellar. These lamellae are irregularly set off and partly wavy. They carry more or less distinct radial riblets, especially on the posterior half of the shell.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 22812.

Remarks.—Odhner (1919, p. 75 and 1955, p. 2) stated that the subgenus *Eopseuma* is chiefly characterized by a furrow separating the cardinal tooth of the right valve into two parts. According to this statement the valve, on which the above description mainly is based, should be referred to *Eopseuma*. However, the other three right valves at hand, two of which (G 11362/1-2) are attached to the specimen described in this report as *Spondylus* aff. *lucasi* Maury, do not show a clear bipartition of the cardinal but only a more or less accentuated crenulation. In other characters they agree well with each other. The only left valve at hand (G 11314) is immature. Its hinge is nearly identical with that of *Pseudochama draconis* (Dall) figured by Odhner (1955, pl. 1, figs. j, k), except that there are no marginal crenulations on the present valve.

Comparisons.—Nicol (1952b, pp. 813-815), in his discussion of the ancestral form of "*Echinochama*," mentioned several fossil species of *Pseudochama*. He stated that *P. riocamica* (Maury) (1917, p. 200, pl. 33, fig. 9) from the Cercado formation of the Dominican Republic is closely related to *P. quirosana*. Both have no crenulations on the inner margin. Maury described the outer surface of the right valve as granulous which is not the case on the present specimens. The original figure is so poor that detailed comparison is impossible. According to Nicol *P. scheibei* (Anderson) (1929, p. 161, pl. 22, figs. 1, 2) from the Miocene of Colombia and *P. corticosaformis* (Weisbord) (1929, p. 18, pl. 4, figs. 2-4), whose type material he studied, might be identical. They both differ from *P. quirosana* in having inner marginal crenulations. *P. draconis* (Dall) (1903, p. 1399, pl. 56, figs. 17, 18) from the Chipola formation of Florida, found to be the probable ancestor of "*Echinochama*" by Nicol, also shows crenulations on the inner

margin and has a nodular sculpture on the right valve. The Recent Floridian *P. inezae* Bayer (1943, p. 122, pl. 15, figs. 33a-d) is a thin-shelled species, whereas *P. quirosana* is heavy.

Occurrence.—N.V.P. Blue No. 3892.

Distribution.—Recorded from Hodson's "Oligocene-Miocene" of Venezuela (District of Miranda, State of Zulia) only.

Genus **ARCINELLA** Schumacher

Schumacher, 1817, *Essai d'un nouveau système des habitations des vers testacés*, p. 142.

Type species (by tautonymy), *Chama arcinella* Linné. Compare Keen, 1962, *Veliger*, vol. 4, No. 4, p. 179.

Arcinella yaquensis (Maury)

Pl. 57, figs. 1, 2

1917. *Echinochama antiquata yaquensis* Maury, *Bull. Amer. Paleont.*, vol. 5, No. 29, p. 201, pl. 33, figs. 11, 12.

1922. *Echinochama yaquensis* Maury, Olsson, *Bull. Amer. Paleont.*, vol. 9, No. 39, p. 219, pl. 28, fig. 5.

1952. *Echinochama yaquensis* Maury, Nicol, *Jour. Paleont.*, vol. 26, No. 5, p. 809, pl. 118, figs. 3, 4.

Shell about as high as long. The outer surface is divided into two parts by a prominent rib carrying several spines with a ventral opening. The anterior smaller portion is occupied anteriormost by a broad lunule, bordered posteriorly by a large and rounded ridge without spines. The remaining space carries one row of spines of secondary size, and in front of it a second one, which, however, is only feebly indicated. Their interspaces are concave causing a slightly wavy outline of the ventral margin. The posterior larger portion is sculptured just behind the primary row of spines by three secondary rows with about equal interspaces, followed by a slightly concave area running from the umbo to the postero-ventral margin. Just posterior to it a last row of spines is present. The roundly produced anterior extremity is caused by the broad ridge behind the lunule. The whole surface is sculptured by knobs except on the spine rows themselves, somewhat irregularly set on the anterior part, but arranged in oblique lines posteriorly. Some growth lines are visible, especially towards the ventral margin. The small attachment area of the juvenile stage is clearly visible just in front of the primary spine row. The inner margin is finely crenulated. The strong and somewhat triangular cardinal tooth is

divided into two unequal parts by a deep transverse furrow. The larger anterior part carries a minor transverse groove. Ligamental area deep and long.

Syntypes (2).—Geology Dept., Cornell Univ. No. 36769 (according to Nicol).

Remarks.—The material studied consists of a single right valve. The figures of Maury and Nicol show less conspicuous spine rows, but Olsson's figure, taken by Nicol in his synonymy, shows distinctly the prominent primary spine row. The left valve of *A. yaquensis* is flatter and not so high, a feature forming one of the reasons why Nicol considers it as the most primitive form of "*Echinochama*." There is no left valve in this material. The right cardinal of the specimen is divided by a furrow principally like that of *Pseudochama draconis*, which is supposed to belong to *Eopseuma* by Odhner (1955, p. 2), and to be the ancestral form of "*Echinochama*" by Nicol. Thus *A. yaquensis* would represent a "direct" descendant of *P. draconis*.

Comparisons.—The specimen closely resembles shells of *A. cornuta* (Conrad) (1866, p. 105), a North American species ranging from Miocene to Recent. The number of spine rows is about the same. The secondary spine rows are more prominent in *A. cornuta* and form real ribs, whereas on the present specimen, the space between two spines of one row may be occupied by the normal knobby sculpture. The group of *A. arcinella* has as a rule more spine rows. *A. arcinella antiquata* (Dall) (1903, p. 1404, pl. 54, fig. 9), of which several specimens from Bowden are at hand, does not develop a prominent primary spine row and its right cardinal is different. *A. trachyderma* (Pilsbry and Johnson) (1917, p. 197; Pilsbry, 1922, p. 416, pl. 46, figs. 1, 2), from the Cercado and Gurabo formations of the Dominican Republic, is a larger species resembling *A. arcinella antiquata* and has a distinct concavity on the posterior half of the shell. *A. collinsi* (Nicol) (1952b, p. 809, pl. 118, fig. 5; pl. 119, fig. 2) has higher umbones and more spine rows. Its right cardinal is not deeply furrowed.

Occurrence.—N.V.P. Blue No. 3892.

Distribution.—Compare Nicol (1952b, p. 809).

Family **CARDIIDAE**Genus **TRACHYCARDIUM** Mörch

Mörch, 1853, *Catalogus Conchyliorum quae reliquit D. Alphonso d'Aguirra et Gadea Comes de Yoldi*, part 2, p. 34.

Type species (by subsequent designation, Von Martens, 1870, *Zool. Rec.* for 1869, vol. 6, p. 586), *Cardium isocardia* Linné.

Subgenus **DALLOCARDIA** Stewart

Stewart, 1930, *Acad. Nat. Sci. Philadelphia*, Spec. Pub. No. 3, p. 264.

Type species (by original designation), *Cardium quadragenarium* Conrad.

Trachycardium (Dallocardia) bowdenense (Dall) Pl. 57, figs. 4, 5

1900. *Cardium* (*Trachycardium*) var. ? *bowdenense* Dall, *Wagner Free Inst. Sci. Philadelphia*, Trans., vol. 3, pt. 5, p. 1087.

? 1925. *Cardium* (*Trachycardium*) *bowdenense* Dall, *Maury, Bull. Amer. Paleont.*, vol. 10, No. 42, p. 128.

1925. *Cardium* (*Trachycardium*) *bowdenense* Dall, *Woodring, Carnegie Inst. Wash.*, Pub. No. 366, p. 137, pl. 18, figs. 14-16.

Syntypes (?).—U.S. Nat. Mus., No. 115667.

Remarks.—There are three valves of this species. Two of them agree well with the original and Woodring's supplementary description. The third (G 11324) differs by the smooth ribs over the central portion of the disc and the obscure beads on the posterior half of the posterior ribs. This detail, however, may also be observed on Recent specimens of *T. muricatum*.

Comparisons.—The differences between *T. bowdenense* and the Pleistocene to Recent *T. muricatum* Linné (1758, *Systema Naturae*, ed. 10, p. 680) have been described by Dall and Woodring. *T. bowdenense* is considered an ancestral form of *T. muricatum*. *T. sanctidavidis* (Maury) (1925, p. 129, pl. 22, fig. 3) from Matura Bay, Trinidad, is similar to both species. It is intermediate in size between them, and thus considered by Maury as a connecting link. Numerous specimens of *T. sanctidavidis* from its type locality are at hand. They differ only from the present shells by their larger size and the more delicate shell. *T. silicatum* (Mansfield) (1937a, p. 253, pl. 19, fig. 3) from the Tampa limestone of Florida is more symmetrical and has somewhat wider ribs. *T. couvense* (Maury) (1925, p. 128, pl. 23, fig. 12) from Springvale, Trinidad, is also considered as an ancestral form of *T. muricatum*. Topotypes of this species at hand are larger than *T. bowdenense*.

more symmetrical, and almost lack the beading of the ribs. Other related forms are mentioned by Woodring.

Occurrence. — N.V.P. Blue No. 3892.

Distribution. — Bowden, Jamaica.

Genus **TRIGONIOCARDIA** Dall

Dall, 1900, Wagner Free Inst. Sci. Philadelphia, Trans., vol. 3, pt. 5, p. 1075.

Type species (by original designation), *Cardium graniferum* Broderip and G. B. Sowerby I.

Subgenus **TRIGONIOCARDIA** s. str.

Trigoniocardia (Trigoniocardia) aff. *ceramida* (Dall) Pl. 57, figs, 3, 6

1886. *Cardium ceramidum* Dall, Bull. Mus. Comp. Zool., vol. 12, No. 6, p. 269, pl. 4, fig. 6.

Remarks. — There is a single well-preserved right valve with 18 ribs, which shows much affinity to *T. ceramida*. There are also four higher and more prominent ribs with interspaces of about their own width, the posteriormost of them forming the posterior angulation. This angulation is somewhat more accentuated than that of the figured type specimen. The beads of the rather narrow, but highly elevated rib forming the posterior angulation, occupy the whole width of the rib. Those of the remaining three strong ribs are restricted to the ventral part of the shell and situated on the posterior half of the rib. The seven ribs on the posterior slope are narrow and carry numerous rounded beads. The seven anterior ribs gradually become lower and narrower. They carry a few beads near the ventral margin. The interspaces lying anterior to the posterior angulation are ornamented by straight or concave (concavity facing upwards) concentric threads. On the posterior slope these threads become obsolete and are replaced by growth lines. The posterior part of the hinge plate is curved downwards. The shell is larger than any recorded specimen of *T. ceramida*.

T. ceramida, which is considered as a descendant of *T. haitensis* by Dall, has been redescribed and refigured by Clench and Smith (1944, p. 20, pl. 11, figs. 5, 6). They clearly separate it from *T. antillarum* (d'Orbigny) (1845, p. 338; 1842, pl. 27, figs. 53-55) indicating a different range for both species, whereas

Warmke and Abbott (1961, 1962, p. 183) consider it as a synonym of *T. antillarum*. The original figures of *T. antillarum* do not show more prominent median ribs, thus justifying the separation of *T. ceramida* as a distinct species.

A relation to the Recent West Coast *T. granifera* (Broderip and G. B. Sowerby I) (see Olsson, 1961, p. 251, pl. 38, fig. 3), the type species of *Trigoniocardia*, is obvious.

Occurrence.—N.V.P. Blue No. 3892.

Trigoniocardia (subgenus ?) **hannai** (Olsson)

Pl. 57, figs. 7, 8, 10

1922. *Cardium* (*Trigoniocardia*) *affinis* Spieker, Johns Hopkins Univ. Studies in Geol., No. 3, p. 136, pl. 8, fig. 3 (not of Nelson, 1870).

1932. *Cardium* (*Trigoniocardia*) *hannai* Olsson, Bull. Amer. Paleont., vol. 19, No. 68, p. 99, pl. 8, figs. 4, 9, 10, 11.

Holotype.—Pal. Res. Inst. Ithaca, New York, No. 2217.

Remarks.—The material studied consists of more than a dozen partly worn valves. As indicated in the original description the ornamentation by beads is variable. The holotype carries beads even on the central ribs, whereas in paratypes they are restricted to the ventral margin, another part of the rib or lacking completely. On an average these valves are somewhat larger than the type specimens, and their posterior angulation is slightly more pronounced.

Comparisons.—*T. aminensis* (Dall) (1900, p. 1104; 1903, pl. 18, fig. 11) from the Gurabo formation of the Dominican Republic has about the same dimensions but a few more ribs. The posterior angulation is somewhat curved, whereas in *T. hannai* it is nearly straight. Topotypes of the Pliocene *T. maturensis* (Dall) (1900, p. 1105; 1903, pl. 48, fig. 7) from Matura, Trinidad, at hand show that Dall's type apparently was a young shell. The largest topotype in the collection reaches a height of 18.2 mm. *T. maturensis* has a more rounded posterior angulation than *T. hannai*. Its ribs are rounded instead of rectangular and asymmetrical with a long slope anteriorly. *T. haitensis* (G. B. Sowerby I) (1850, p. 52, pl. 10, fig. 11; lectotype figured by Pflug 1961, pl. 24, figs. 10, 11) from the Cercado formation of the Dominican Republic reaches a larger size. Its hinge plate is less curved, and it has a more or less pronounced postero-dorsal angulation, whereas in *T. hannai*

the posterior margin steeply slopes down from the hinge.

Occurrence.—N.V.P. Blue No. 3892, Re 1148.

Distribution.—Lower Zorritos formation (lower Miocene), Perú.

Family **VENERIDAE**

Genus **CYCLINELLA** Dall

Dall, 1902, *Nautilus*, vol. 16. No. 4, p. 44.

Type species (by original designation), *Dosina (Artemis) tenuis* Récluz.

Cyclinella venezuelana H. K. Hodson

Pl. 57, fig. 9

1927. *Cyclinella venezuelana* H. K. Hodson, in Hodson, Hodson, and Harris, *Bull. Amer. Paleont.*, vol. 13, No. 49, p. 59, pl. 34, figs. 3, 4.

Shell produced antero-dorsally. Umbones low. Ventral margin strongly arched. Posterior side nearly straight and vertical. Sculpture consists of fine incrementals which become somewhat more conspicuous towards the ventral margin. Border line of lunule inconspicuous. No escutcheon. Pallial sinus deep, not pointed.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 22838.

Remarks.—The material consists of numerous badly preserved specimens. Some of them are casts. On one of them (G 11329) the muscle scars and the pallial line are well recognizable. There is no single valve, so that the hinge of this species is still not known. The holotype of *C. venezuelana* came from Hodson's locality No. 2207 (Cantaure).

Comparisons.—The main difference between the Venezuelan species and *C. gatunensis* Dall (1903, p. 1285, pl. 52, fig. 18) from the Gatún formation of the Panamá Canal Zone seems to consist in the greater convexity of the former. *C. gatunensis* is somewhat more produced antero-dorsally and more regularly curved ventrally. *C. beteyensis* Olsson (1922, p. 242, pl. 31, fig. 2) from the Gatún formation of Costa Rica, although known only from an imperfect holotype, seems to be more circular in outline. *C. plasiatenuis* Woodring (1925, p. 158, pl. 21, figs. 10, 11) from Bowden, Jamaica, is a smaller species of more circular shape and has a stronger concentric sculpture. *C. cyclica* (Guppy) (1866b, p. 582, pl. 26, fig. 5) from Manzanilla, Trinidad, is clearly dis-

tinguished by its more circular outline and the more conspicuous concentric striae. *C. harrisi* Palmer (1927-1929, p. 199, pl. 45, figs. 6, 7) from Springvale, Trinidad, of which a topotype is at hand, is also more orbicular in shape, less convex, has less prominent umbones, but a stronger sculpture. The Recent Pacific *C. jadisi* Olsson (1961, p. 264, pl. 43, figs. 2, 2a) and *C. subquadrata* (Hanley) (1845, p. 11; Olsson 1961, p. 263, pl. 55, fig. 2) are much larger species but are similar in outline and sculpture. The pallial sinus of *C. jadisi* is narrower.

Occurrence.—N.V.P. Blue No. 3892. Re 1148, Re 1154, Re 1199.

Distribution.—Miocene of Falcón, Venezuela (Hodson).

Genus **CLEMENTIA** Gray

Gray, 1842, Synopsis of the contents of the British Museum, ed. 44, p. 75.

Type species (by subsequent designation, Gray, 1847, Zool. Soc. London, Proc., pt. 15, p. 184), *Venus papyracea* Gray.

Subgenus **CLEMENTIA** s. str.

Clementia (Clementia) dariena (Conrad)

Pl. 57, figs. 11, 12;
Pl. 58, figs. 1-3

- 1855. *Meretrix dariena* Conrad, House Doc. No. 129, p. 18. Reprint, Dall, 1909, U.S. Geol. Sur., Prof. Paper 59, p. 170.
- 1909. *Clementia dariena* (Conrad), Toulou, Jahrb. K.K. geol. Reichsanstalt, vol. 58, p. 725, pl. 27, figs. 9, 10.
- 1920. *Clementia rabelli* Maury, New York Acad. Sci., Sci. Sur. Porto Rico and Virgin Islands, vol. 3, pt. 1, p. 37, pl. 6, figs. 2, 3.
- 1922. *Clementia dariena* (Conrad), Olsson, Bull. Amer. Paleont., vol. 9, No. 39, p. 232, pl. 31, fig. 4.
- 1922. *Clementia dariena* (Conrad), Spieker, Johns Hopkins Univ. Studies in Geol., No. 3, p. 141, pl. 8, fig. 5.
- 1925. *Clementia dariena* (Conrad), Maury, Bull. Amer. Paleont., vol. 10, No. 42, p. 141, pl. 26, figs. 1, 3, 5, 6, 7.
- 1926. *Clementia (Clementia) dariena dariena* (Conrad), Woodring, U.S. Geol. Sur., Prof. Paper 147, p. 34, pl. 14, figs. 6-11. For additional citations see this publication.
- 1926. *Clementia (Clementia) dariena rabelli* Maury, Woodring, *idem*, p. 34, pl. 14, fig. 5.
- 1927. *Clementia dariena* (Conrad), Palmer, Palaeont. Amer., vol. 1, No. 5, p. 202, pl. 26, figs. 6, 13-20.
- 1932. *Clementia (Clementia) dariena* (Conrad), Olsson, Bull. Amer. Paleont., vol. 19, No. 68, p. 102.
- 1960. *Clementia (Clementia) dariena* (Conrad), Barrios, Bol. Geol., vol. 6, Nos. 1-3, Informe No. 1082, p. 258, pl. 7, fig. 7.

Sculpture consists of regular concentric waves carrying fine threads. In young stages these are more or less equally spaced.

Entering the area behind and the areola in front of the beaks the waves diminish rapidly. In very young stages the dorsal slope of the waves is somewhat steeper than the ventral side. With increasing age the waves become almost symmetrical in cross section. Later on their dorsal side develops to a relatively broad and flat region, whereas the ventral slope tends to be short, steep, and sometimes even concave. In the adult stage the waves disappear gradually and are replaced by distinct and rather regular growth lines with intervening threads.

Neotype. — U.S. Nat. Mus., No. 354038.

Remarks. — As stated by Spieker (1922, p. 142) there is no lunule. The whole areola is characterized by threads leading from the concentric sculpture towards the umbones. Escutcheon narrow and deep. The only short description and figure of the hinge of this species is to be found in Toula (1909, p. 725, pl. 27, fig. 10). The anteriormost cardinal tooth is straight, narrow, and high. Just posterior to it there is a second cardinal tooth which is slightly curved in its dorsal part towards the first cardinal causing a corresponding narrowing of the deep interspace. Posterior to a triangular groove follows a third, long cardinal tooth which is doubled in its postero-ventral part.

There are about 50 specimens from Central Paraguaná. Nearly all of them have at least parts of the shell preserved. One right valve (G 11331) from Re 1148 shows the hinge described above (see Pl. 57, fig. 12). The largest specimens reach a length of 55 mm. They all show the typical sculpture of the adult, or even gerontic stage: irregularly spaced growth lines, in general less accentuated towards the ventral margin of the shell. At this age they have the characteristic inequilateral outline. Looking at young individuals (some of them occurring together with adult ones are at hand) one states that they have a less inequilateral appearance (compare Palmer, 1927, 1929, p. 202). This is due to the circumstance that the rate of growth in the region around the umbonal ridge is higher than elsewhere, especially in later stages. This fact may lead to a bad orientation of the specimens in a system of coordinates, thus evidently influencing a morphological description.

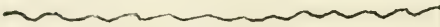
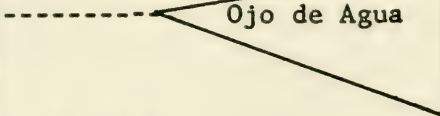
Formation	Occurrence
Tucupido	o
	o
Punta Gavilán	o
 Ojo de Agua	ooooo ooooo ooooo o
La Vela	ooooo
Caujarao	ooooo
Socorro	x
Querales	
Cerro Pelado	ooooo xxx
Agua Clara	
San Luis	x

Table 3. Distribution of large and small specimens of *Clementia dariena*.
 o = localities with specimens exceeding 60 mm in length. x = localities with
 specimens smaller than 37 mm in length.

Besides the specimens from Central Paraguaná there is a collection of *Clementias* from central and eastern Falcón which come from 120 localities. In the stratigraphic discussion of the *Clementia dariena* group in the literature the size of the specimens is of main importance (Woodring, 1926; Olsson, 1928, p. 34). "The increase in size of progressively younger specimens is the most striking feature of this series" (Woodring, 1926, p. 34). The size was the final criterion for the establishment of *Clementia rabelli* Maury.

Table 3 shows that the general increase in size of the *Clementias* is true but *not* continuous. Specimens from 34 localities exceeding 60 mm. in length are picked out and marked on Table 3 according to their stratigraphic occurrences. An obvious accumulation in the La Vela formation and in its time equivalent, the Ojo de Agua formation, is stated.

On the other hand, the same procedure was applied to little specimens (not exceeding 37 mm. in length) from five localities: all of them are older than Caujarao.

The 14 well-preserved specimens from the Socorro formation (N.V.P. Blue No. 2066) overlap the range of the large-sized individuals considerably. Full-grown they show the characteristic changes of sculpture near the ventral margin (Pl. 58, fig. 3). When compared with Maury's description and figure of the holotype of *C. rabelli*, its identity is obvious. It is questionable, however, if subspecific rank can be given to slight differences in outline and size. Seven casts, partly distorted, from the San Luis formation (N.V.P. Blue No. 1138) indistinctly showing the adult sculpture are difficult to identify. They could be referred to *C. peruviana* Olsson (1928, p. 33, pl. 7, figs. 1, 2, 7), a species reaching up to the Heath formation of Perú. It is compared to *C. dariena* and *C. dariena vetula* by Olsson.

Occurrence.—N.V.P. Blue No. 3892, Re 1148, Re 1152, Re 1154, Re 1155, Re 1199.

Distribution.—*Fide* Woodring (1926), pp. 35-36).

Genus **MACROCALLISTA** Meek

Meek, 1876, Rept. U.S. Geol. Survey of the Territories, vol. 9, p. 179.

Type species (by monotypy), *Venus gigantea* Gmelin (= *Venus nimbose* Solander).

Macrocallista maculata (Linné)

Pl. 58, figs. 4-6

1758. *Venus maculata* Linnaeus, *Systema Naturae*, ed. 10, p. 686.
 1926. *Macrocallista* (*Paradione*) *maculata* (Linnaeus), Gardner, U.S. Geol. Sur., Prof. Paper 142-D, p. 160.
 1927. *Callista* (*Callista*) *maculata* (Linnaeus), Palmer, *Palaeont. Amer.*, vol. 1, No. 5, p. 77, pl. 10, fig. 11; pl. 12, figs. 1, 2, 3, 8, 9; pl. 14, fig. 4. For additional citations see this publication.
 1927. *Macrocallista maculata* (Linné), Hodson, Hodson, and Harris, *Bull. Amer. Paleont.*, vol. 13, No. 49, p. 54, pl. 32, fig. 6.
 1927. *Pitaria* (*Pitaria*) *quirosana* H. K. Hodson, in Hodson, Hodson, and Harris, *idem*, p. 55, pl. 32, figs. 2, 5.
 1931. *Callista maculata quirosana* (H. K. Hodson), in Hodson and Hodson, *Bull. Amer. Paleont.*, vol. 16, No. 60, p. 7.
 1940. *Macrocallista maculata* (Linné), Perry, *Bull. Amer. Paleont.*, vol. 26, No. 95, p. 64, pl. 13, fig. 82.
 1942. *Macrocallista maculata* (Linné), Clench, *Johnsonia*, vol. 1, No. 3, p. 6, pl. 5.
 1954. *Macrocallista maculata* (Linné), Abbott, *American Seashells*, p. 416, pl. 1b, pl. 39e.
 1962. *Macrocallista maculata* (Linné), Warmke and Abbott, *Caribbean Seashells*, p. 189, pl. 39f.

Remarks.—This species is represented in the collections from several localities in Falcón and Trinidad. The specimens from Paraguaná are smaller. The material from Springvale mentioned by Rutsch (1942, p. 102) contains much larger specimens, which are, in addition, more elongate. Numerous Recent shells of different growth stages from Barbados are at hand. Most of them have the dimensions of the fossil specimens and are practically identical with them. The anterior lateral tooth of the left valve is somewhat elongate posteriorly in the material from Paraguaná which is not the case in the Recent shells. Moreover, there is a slight accentuation of the umbonal ridge, which, otherwise, does not seem to be typical. The specimens from Paraguaná are considered to be immature. *Pitaria quirosana* H. K. Hodson probably also represents an immature *M. maculata*.

Comparisons.—*M. waltonensis* Gardner (1926, p. 161, pl. 24, figs. 8, 9) from the Shoal River formation of Florida has a somewhat less curved postero-dorsal margin, and the pallial sinus is shallower and less pointed anteriorly. *M. waltonensis vaughanensis* Mansfield (1932a, p. 121, pl. 25, figs. 7, 10) from the *Arca* Zone

(upper middle Miocene) of Florida is even more elongate than *M. waltonensis* s.str., but has a pointed pallial sinus. Another still more elongate form is *M. reposta* (Conrad) (1834, p. 132) from the Miocene of Virginia (see also Gardner 1943, p. 123, pl. 19, figs. 1-3, 5). Its posterior extremity is somewhat pointed, and there is a clear concavity between beak and anterior end. The description of *M. pirabica* Maury (1924, p. 323, pl. 18, fig. 14) from Brazil is based on internal molds. According to Maury it is distinguished from *M. maculata* by its heavier teeth.

Occurrence.—N.V.P. Blue No. 3892.

Distribution.—See Palmer (1927-1929, p. 78).

Genus **PITAR** Römer

Pitar Römer, 1857, Kritische Untersuchung der Arten des Molluskengeschlechts Venus bei Linné und Gmelin, p. 15.

Pitaria Palmer, 1927, Palaeont. Amer., vol. 1, No. 5, p. 8.

Type species (by monotypy), *Venus tumens* Gmelin.

Subgenus **PITARELLA** Palmer

Palmer, 1927, Palaeont. Amer., vol. 1, No. 5, p. 35.

Type species (by original designation), *Pitar gatunensis* (Dall).

Several names, such as *Callocardia*, *Agriopoma*, *Pitarella*, have been used as genera or subgenera. Palmer placed them all as subgenera under *Pitar*. Their differences consist in slight hinge modifications, and it is doubtful, if these modifications deserve subgeneric rank. The subgeneric assignment becomes extremely subjective, when a characteristic like the distance between the left anterior lateral and cardinal has to be an important diagnostic feature. *P. calceolus* (Gardner) (1936, p. 30, pl. 7, figs. 3, 4) is an example. This species is extremely similar to *P. paraguayanensis* but is put under another subgenus, practically because the distance between the left anterior lateral and cardinal is somewhat greater than in *P. paraguayanensis*. Comparison of the type species of each of these "supraspecific" categories would perhaps justify the union of at least two of them.

Pitar (Pitarella) paraguayanensis (H. K. Hodson)

Pl. 58, figs. 7-9

1927. *Pitaria* (*Pitaria*) *paraguayanensis* H. K. Hodson, in Hodson, Hodson, and Harris, Bull. Amer. Paleont., vol. 13, No. 49, p. 56, pl. 33, fig. 1.

Addenda to original description.—Inner margin smooth. Palial sinus deep and narrow. Hinge of left valve: three cardinal teeth. Posterior one oblique, long, with a faint medial groove. The anterior ones short, joint dorsally. Middle cardinal thickening rapidly ventrally. In addition there is an anterior small and pointed lateral tooth. Hinge of right valve: three cardinal teeth. Posterior one oblique, broad, and bifid. The two anterior ones short, narrow, and parallel. Below the pit for the left anterior lateral tooth there is a small projection.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 22830.

Remarks.—Among the rich material young individuals, as well as intermediate and adult growth stages, are represented. All the free hinges belong to young shells, so that there is a point of doubt, whether these smaller shells really belong to this species. The faint incised line, which forms the border of the lunule, becomes less distinct in later stages. Adult shells are more produced anteriorly.

Comparisons.—The type species of *Pitarella*, *P. gatunensis* (Dall) (1903, p. 1260, pl. 54, fig. 1) from the Gatún formation of the Panamá Canal Zone, material of which from Mt. Hope, Gatún, is at hand, shows a greater convexity. Its umbones are somewhat lower, and situated more anteriorly, or, in other words, *P. paraguanensis* is more produced anteriorly. *P. paraguanensis* seems to reach a larger size, the largest specimen (G 11222) measuring 56 mm. in length compared to 38 mm. (holotype) and 51 mm. (largest specimen of *P. gatunensis* from Mt. Hope). *P. gatunensis multifilosus* (Dall) (1903, p. 1261, pl. 54, fig. 15), also from the Gatún formation of the Panamá Canal Zone, has some sculptural elements, which are more pronounced (even in younger stages) than the others, whereas in *P. paraguanensis* the incrementals gradually become more conspicuous towards the ventral margin. It is difficult to point out differences to *P. cercadicus* (Maury) (1917, p. 216, pl. 37, fig. 10) from the Cercado formation of the Dominican Republic with the help of descriptions and figures alone. Palmer (1927-1929, p. 37), who studied the holotype and compared it with topotype material of *P. gatunensis*, considered it as a distinct species. The only known valve of this species is much smaller than the adult specimens of *P. paraguanensis* but may be immature. *P. colinensis* (H. K. Hodson) (in Hodson, Hod-

son and Harris, 1927, p. 56, pl. 33, figs. 4, 6) from the Caujarao formation of Falcón, which cannot be determined subgenerically because the hinge is not known, is much less produced anteriorly and is relatively higher compared with the length than *P. paraguayensis*. *P. mancorensis* (Olsson) (1931, p. 56, pl. 7, figs. 2, 5) from the Mancora formation of Perú has higher umbones than *P. paraguayensis*, and *P. tumbezanus* (Olsson) (1932, p. 107, pl. 10, figs. 1, 3) from the Cardalitos formation of Perú is a less elongate form. *P. calceolus* (Gardner) (1936, p. 30, pl. 7, figs. 3, 4) from the Shoal River formation of Florida is similar and cannot be distinguished with description and figures only.

Occurrence.—N.V.P. Blue No. 3892, Re 1148, Re 1152, Re 1153, Re 1154, Re 1155, Re 1199.

Distribution.—Known from type locality only.

Subgenus **LAMELLICONCHA** Dall

Dall, 1902, U.S. Nat. Mus., Proc., vol. 26, No. 1312, p. 354.

Type species (by original designation), *Cytherea concinna* G. B. Sowerby I.

Pitar (Lamelliconcha) circinatus (Born)

Pl. 59, figs. 1-3

1780. *Venus circinata* Born, Testacea Musei Caesarei Vindobonensis, p. 61, tab. 4, fig. 8.

1927. *Pitaria (Lamelliconcha) circinata* (Born), Palmer, Paleont. Amer., vol. 1, No. 5, p. 48, pl. 9, figs. 10, 11, 12, 15, 16, 19. For additional citations see this publication.

1931. *Pitaria (Lamelliconcha) circinata* (Born), Hodson and Hodson, Bull. Amer. Paleont., vol. 16, No. 59, p. 10, pl. 4, figs. 5, 7.

1962. *Pitar circinata* (Born), Warmke and Abbott, Caribbean Seashells, p. 189, pl. 39j.

Types.—According to a letter from Dr. O. Paget, dated December 6, 1963, there are three syntypes in the Natural History Museum of Vienna with the numbers 76522, 76523, and 76524.

Remarks.—There are about 20 excellently preserved shells of different growth stages. The outline of the shell is not constant. It may be more or less elongate, *i.e.* the anterior margin may be somewhat pointed. The postero-dorsal margin is generally slightly arched but may be straightened.

Comparisons.—*P. petersoni* (Olsson) (1932, p. 109, pl. 11, fig. 6) from the Zorritos formation of Perú is higher, the posterior side is truncated, and the umbonal slope is separated from the

main shell disc by a slight angulation. In this last respect it approaches *P. thompsoni* Marks (1951, p. 74, pl. 4, figs. 6, 7) from the Gatún formation of Panamá. The Pliocene *P. anonus* (Olsson) (1942, p. 37, pl. 5, fig. 1) from Panamá is hardly distinguishable from *P. petersoni* with the help of the figures alone. It has also a truncated posterior side and an angulation between umbonal slope and main shell disc. Other comparisons have been made by Palmer (1927, 1929, p. 49).

Occurrence.—N.V.P. Blue No. 3892

Distribution.—See Palmer (1927, 1929, p. 50).

Genus **ANTIGONA** Schumacher

Schumacher, 1817, *Essai d'un nouveau système des habitations des vers testacés*, p. 154.

Type species (by monotypy), *Antigona lamellaris* Schumacher.

Subgenus **VENTRICOLARIA** Keen

Keen, 1954, *Jour. Pal.*, vol. 28, No. 2, p. 218.

Type species (by original designation), *Venus rigida* Dillwyn.

Antigona (Ventricolaria) palmerae H. K. Hodson Pl. 59, figs. 4, 5

1927. *Antigona (Ventricola) palmerae* H. K. Hodson in Hodson, Hodson, and Harris, *Bull. Amer. Paleont.*, vol. 13, No. 49, p. 58, pl. 31, figs. 6, 7; pl. 35, fig. 8.

Addenda to original description.—Shell elliptical in outline, inequilateral. In young stages there are about five secondaries between the concentric lamellae. With increasing age their number is reduced to two or three, and a few tertiary threads may appear. Radial element of sculpture missing except a few weak indications on the posterior half of the shell. Hinge of left valve consists of a small anterior lateral and three cardinals. Anterior cardinal slenderly trigonal; slightly bifid ventrally. Middle cardinal broad and strongly bifid. Posterior lateral oblique, long, and narrow. Pallial sinus not deep, pointed.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 22825.

Remarks.—The material consists of two left valves which are not complete. One of the hinges is only badly preserved, so that the above description of the hinge is based on a single specimen.

Comparisons.—*A. blandiana* (Guppy) (1873a, p. 85; reprint, Harris 1921, p. 69), some specimens from Bowden, Jamaica, are at hand, is more produced anteriorly, more inflated, and has higher beaks. The left anterior cardinal is somewhat curved, the concave side facing upwards, whereas in *A. palmerae* it is straight. The left middle cardinal has a less conspicuous sulcus. The Recent *A. rigida* (Dillwyn) mainly differs by its more elongate and inequilateral shape. The Pliocene to Recent *A. rugatina* (Heilprin) (1887, p. 92, pl. 11, figs. 24, 24a) is strongly produced anteriorly causing a concavity between beaks and anterior extremity. Its umbones are higher, and according to the original figures it seems to be more inflated. *A. sanctaenoclis* Maury (1925, p. 339, pl. 18, fig. 13) from the Miocene of Brazil is more circular in outline, has less secondaries between the concentric lamellae, and shows a weak radial sculpture over the entire surface of the shell.

Occurrence.—N.V.P. Blue No. 3892.

Distribution.—"Oligocene-Miocene" of Falcón and Zulía, Venezuela (Hodson).

Genus **CHIONE** Megerle von Mühlfeld

Megerle von Mühlfeld, 1811, Mag. Ges. Naturf. Freunde zu Berlin, vol. 5, p. 51.

Type species (by subsequent designation, Gray, 1847, Zool. Soc. London, Proc., pt. 15, p. 183), *Venus dysera* Chemnitz (= *Venus cancellata* Linné).

Subgenus **CHIONOPSIS** Olsson

Olsson, 1932, Bull. Amer. Paleont., vol. 19, No. 68, p. 111.

Type species (by original designation), *Chione amathusia* (Philippi).

Chione (Chionopsis) paraganensis H. K. Hodson Pl. 59, figs. 6-9

1927. *Chione (Chione) paraganensis* H. K. Hodson, in Hodson, Hodson, and Harris, Bull. Amer. Paleont., vol. 13, No. 49, p. 62, pl. 35, figs. 2, 7.

Addenda to original description.—Shell circular in outline in young stages but produced posteriorly in later stages. Just in front of the umbonal ridge there is a slight depression. The radial sculpture consists of equidistant simple ribs in young stages which become doubled subsequently. Between these paired ribs, which are confined to the central portion of the main shell disc, an additional riblet appears. Lunular border above hinge crenulated. The

posterior two right cardinals are slightly bifid. The posteriormost one is trigonal and broad ventrally. Anterior right cardinal narrow. Middle left cardinal bifid, connected dorsally with the slenderly trigonal anterior cardinal. Posterior left cardinal oblique, long and narrow. Crenulation of inner margin at posterior production much less conspicuous.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 22844.

Variability.—The outline of the shell is not constant due to the variability of the following two elements. First: The posterior production is more or less conspicuous. If it is accentuated, the above mentioned concavity in front of the umbonal ridge at the same time becomes deeper. Otherwise it is shallow. Second: The angle between the straight postero-dorsal and the antero-dorsal margins is not constant.

Remarks.—The material consists of about 50 well-preserved single valves of all growth stages. Both, right as well as left valves, are well represented, but there is no individual with joint valves.

Comparisons.—A comparison with *C. propinqua* Spieker (1922, p. 152, pl. 9, fig. 12) from the Zorritos formation of Perú has been made by Olsson (1932, p. 113). Topotypes of *C. walli* (Guppy) (1866b, p. 581, pl. 26, fig. 16) are at hand. This species, although similar to *C. paraguayensis*, differs by a less marked posterior production giving higher aspect to the shell. In addition *C. paraguayensis* has more convex valves. *C. rowleei* Olsson (1922, p. 244, pl. 30, fig. 2) from the Gatún formation of Costa Rica (two specimens from Banana River, Costa Rica, are at hand) is a much larger and thick-shelled species [in this respect approaching *C. atlanticana* Anderson (1929, p. 172, pl. 23, figs. 5, 6)] with correspondingly coarser sculpture. The figure given by Palmer, (1927, 1929, pl. 39, fig. 22) suggests a similar form differing from *C. paraguayensis* by its broader umbones and less produced posterior side. Whether or not *C. bolivarensis* Weisbord (1929, p. 22, pl. 5, figs. 2, 3) belongs to the subgenus *Chionopsis* cannot be decided with the help of the original figure only. It has fewer concentric lamellae and apparently no doubled radials. The posterior production is not marked. The Pliocene *C. manabia* Pilsbry and Olsson (1941, p. 62, pl. 16, figs. 1, 3) from Ecuador is

much larger, has broader umbones, and fewer concentric lamellae. The Recent West Coast type of *Chionopsis*, *C. amathusia* (Philippi) (1844, Abb. und Beschreib. Conch., p. 129, pl. 2, fig. 4) has a different concentric sculpture. The posteriormost point of the shell lies considerably higher than in *C. paraguayensis*. The Recent Caribbean *C. pinchoti* Pilsbry and Olsson (1951, p. 109, pl. 9, figs. 7, 8) has broader umbones, is less pointed posteriorly, and seems to remain smaller than *C. paraguayensis*.

Occurrence.—N.V.P. Blue No. 3892, Re 1199.

Distribution.—Miocene of the State of Falcón, Venezuela.

Subgenus **LIOPHORA** Conrad

Conrad 1863, Acad. Nat. Sci. Philadelphia, Proc. for 1862, pp. 575, 586.

Type species (by subsequent designation, Dall, 1902, U.S. Nat. Mus. Proc., vol. 26, No. 1312, p. 358), *Circomphalus athleta* Conrad (= *Venus latilirata* Conrad).

Chione (Liophora) quirosensis H. K. Hodson

Pl. 60, figs. 1, 2, 4

1927. *Chione (Liophora) quirosensis* H. K. Hodson, in Hodson, Hodson, and Harris, Bull. Amer. Paleont., vol. 13, No. 49, p. 62, pl. 35, fig. 9.

1927. *Chione (Liophora) quirosensis queralana* H. K. Hodson, *idem*, p. 63, pl. 34, fig. 1.

Addenda to original description.—Ventral margin evenly rounded. Anterior and posterior margins produced, somewhat pointed. Inner margin crenulated, including the border of the lunula. Crenulation inconspicuous at posterior extremity, completely lacking on the feebly arched postero-dorsal margin. Right hinge consists of three cardinals. Anterior cardinal reduced, small, narrow, and relatively short. Middle cardinal somewhat trigonal, with a sulcus dorsally. The posterior cardinal is the longest one, oblique, feebly bifid dorsally. Left anterior cardinal trigonal, narrow dorsally. Left middle cardinal broad, slightly bifid. Left posterior cardinal oblique, narrow, long, rugose. Pallial sinus moderately deep, pointed.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 22850.

Variability.—*C. quirosensis* is constant in outline. If anterior and posterior muscle scars are put in a horizontal line, the posterior extremity lies below the anterior one. In young specimens they lie at about the same height. The width of the interspaces

between the concentric lamellae, and thus their number varies greatly.

Remarks.—H. K. Hodson's subspecies *C. queralana* is said to differ from *quirosensis* s.str. by its larger size and the greater number of the concentric lamellae. The crowding of the lamellae towards the ventral margin in large specimens is probably a gerontic feature. Among the well-preserved material there are specimens of the dimensions of the holotype of *C. queralana* with distant lamellae together with other shells which have narrower interspaces. Because these specimens are from the same locality, and because several intergrading stages are represented, I consider *C. queralana* as a synonym of *C. quirosensis*.

Comparisons.—The sculptural pattern of *C. quirosensis* is not frequent. It recalls in some way *C. xesta* Dall (1903, p. 1297, pl. 55, fig. 18) from the Miocene of Alum Bluff, Florida. This species, however, is relatively higher, and has a feeble radial sculptural element which is completely lacking in *C. quirosensis*. *C. crossota* Gardner (1936, p. 34, pl. 7, fig. 8) from the Shoal River formation of Florida is more elongate, more concave between beak and anterior extremity, and has a weak radial sculpture on the ventral side of the concentric lamellae.

Occurrence.—N.V.P. Blue No. 3892, Re 1148, Re 1153, Re 1154, Re 1193, Re 1199.

Distribution.—"Oligocene-Miocene" of Falcón and Zulía, Venezuela (Hodson).

Family **MACTRIDAE**

Genus **MACTRA** Linné

Linné, 1767, *Systema Naturae*, ed. 12, p. 1125.

Type species (by subsequent designation, Gray 1847, *Zool. Soc. London, Proc.*, pt. 15, p. 185), *Mactra stultorum* (Linné).

Subgenus **MICROMACTRA** Dall

Dall, 1894, *Nautilus*, vol. 8, No. 4, p. 40.

Type species (by monotypy), *Mactra californica* Conrad.

Mactra (Micromactra) maracaibensis H. K. Hodson Pl. 60, figs. 3, 5

1931. *Mactra californica maracaibensis* H. K. Hodson, in Hodson and Hodson, *Bull. Amer. Paleont.*, vol. 16, No. 59, p. 20, pl. 9, figs. 6, 19.

? 1942. *Mactra* (*Micromactra*) aff. *macescens* (Guppy), Rutsch, *Verh. Naturf. Ges. Basel*, Bd. 54, p. 119.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 24052.

Remarks.—There are but a few specimens of this species. One left hinge (G 11354) with its divided cardinal, the large resilifer, and the two long and narrow laterals is preserved. Pallial sinus not deep, rounded anteriorly; its axis subparallel to ventral margin. The shells have the dimensions of Hodson's type specimens. There is a specimen (G 11355) from the Ojo de Agua formation of Falcón, however, which reaches a length of 45 mm.

Comparisons.—As stated in the original description *M. maracaibensis* carries two ridges on the postero-dorsal slope. The specimen described by Rutsch (1942, p. 119) as *M. aff. macescens* (Guppy) from Brechin Castle Estate, Trinidad, which is at hand, also shows two ridges. It reaches the dimensions of the above mentioned specimen from the Ojo de Agua formation and is practically identical with it. The umbones of *M. macescens* (Guppy) (1866b, p. 581, pl. 26, fig. 2) are situated behind the center, whereas *M. maracaibensis* is nearly equilateral. *M. macescens* has only one postero-dorsal ridge, and according to the original and Maury's (1925, pl. 21, fig. 1) figure the concentric undulations are developed, at least in front of the umbonal ridge, down to the central portion of the shell. Since the variability of *M. macescens* is not yet known, definite comparative remarks cannot be given. The Pliocene *M. atacama* Pilsbry and Olsson (1941, p. 73, pl. 14, figs. 1, 3) from western Ecuador is synonymous with the Recent West Coast *M. angusta* Reeve (1854, Conch. Icon., vol. 8, *Macra*, pl. 18, fig. 93; Olsson 1961, p. 325, pl. 57, figs. 2-2b, pl. 85, fig. 9). *M. angusta* has about the same proportions as *M. maracaibensis* but seems to attain a much larger size. The holotype, however, which has been refigured by Olsson, is smaller and shows a second postero-dorsal ridge like *M. maracaibensis*. Other similar forms are mentioned by Rutsch (1942, p. 120).

Occurrence.—N.V.P. Blue No. 3892, Re 1199.

Distribution.—Known hitherto from holotype locality (Miocene) only, State of Zulia, Venezuela.

Subgenus **MACTROTOMA** Dall

Dall, 1894, Nautilus, vol. 8, No. 3, p. 26.

Type species (by original designation), *Mactra fragilis* Gmelin.

Mactra (Mactrotoma ?) quirosana H. K. Hodson Pl. 60, figs. 6, 7

1931. *Mactra (Mactrotoma) quirosana* H. K. Hodson in Hodson and Hodson, Bull. Amer. Paleont. vol. 16, No. 59, p. 20, pl. 9, figs. 5, 7, 9.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 24053.

Remarks.—A single left valve of this species is at hand. As stated by Hodson the cardinal tooth extends over the whole width of the hinge plate, and its posterior arm does not project over the chondrophore as shown by Dall (1898, pl. 27, fig. 18) for *M. fragilis* Gmelin, the type species of *Mactrotoma*. For this reason the subgeneric assignment is questionable. Pallial sinus broad and rounded, not deep.

Comparisons.—*M. fragilis* Gmelin (1790, Systema Naturae, ed. 13, vol. 1, p. 3261; Warmke and Abbott 1961, 1962, pl. 43g) is a larger and more elongate species. Its umbonal ridge is more accentuated. *M. willcoxi* Dall (1898, p. 894, pl. 28, figs. 10, 11) is much larger, and its dorsal margins are slightly concave instead of convex as in *M. quirosana*.

Occurrence.—N.V.P. Blue No. 3892.

Distribution.—Known hitherto from holotype locality (Hodson's locality No. 6 = Quiroz) only (lower Miocene).

Family SANGUINOLARIIDAE

Genus PLEIORYTIS Conrad

Conrad, 1862, Acad. Nat. Sci. Philadelphia, Proc. for 1862, p. 286.

Type species (by monotypy), *Pleiorytis ovata* Conrad (= *Petricola centenaria* Conrad).

Gardner (1936, p. 39; 1943, p. 118) pointed out the differences between *Asaphis* and *Pleiorytis*. Because there is no free hinge, and because the beaks of the material are slightly prosogyrate, I tentatively assign the species described below to *Pleiorytis*.

Pleiorytis caroniana (Maury) Pl. 60, fig. 8

1925. *Petricola caroniana* Maury, Bull. Amer. Paleont., vol. 10, No. 42, p. 122, pl. 20, fig. 16.

1929. *Asaphis delicatus* Weisbord, Bull. Amer. Paleont., vol. 14, No. 54, p. 25, pl. 5, figs. 4, 5.

1938. *Pleiorytis caroniana* (Maury), Vokes, American Museum Novitates, No. 988, p. 15, fig. 11.

Shell reaching a large size, inequilateral. Anterior margin evenly curved. Postero-dorsal margin sloping down. Posterior side straight. Postero-ventrally produced. Ventral margin only slightly curved. Beaks prosogyrate. Umbonal ridge flattening out towards the postero-ventral extremity in adult specimens. Sculpture consists of concentric lines and numerous radial riblets. The concentric lines, which become more conspicuous and closer set towards the ventral margin, divide the surface into a number of bands of different width. The radials of these bands may be set off and curved but always remain parallel.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 883.

Remarks.—There is a single, large, double-valved specimen from Paraguaná. It is more produced postero-ventrally and more inequilateral than the shell figured by Vokes. Unfortunately I do not have topotypes of this species (Rutsch 1942, p. 106), but two of the specimens from the Caujarao formation of the Cumarebo area, which are at hand, have practically the same shape as Vokes' shell. The Venezuelan material shows that young specimens are less produced postero-ventrally than adult ones. It is possible that these differences in shape would prove to fall within the variability, if a large series of specimens were at hand. The Venezuelan specimen of *Asaphis delicatus* figured by Weisbord is identical in outline with the specimens studied and considered synonymous with *P. caroniana* by Vokes.

Comparisons.—*Petricola millestriata* Brown and Pilsbry (1913, p. 516, pl. 26, fig. 2) from the Gatún formation of the Panamá Canal Zone is known from casts only. It is similar in outline to young Venezuelan specimens, and well-preserved shells from Panamá would perhaps prove to be identical with *P. caroniana*. It is less inequilateral and has about the same height anteriorly and posteriorly, whereas *P. caroniana* is higher posteriorly.

Occurrence.—N.V.P. Blue No. 3892.

Distribution.—Springvale formation, Trinidad. Middle Miocene of Venezuela and Colombia.

Family SEMELIDAE

Genus SEMELE Schumacher

Schumacher, 1817, Essai d'un nouveau système des habitations des vers testacés, p. 165.

Type species (by monotypy), *Tellina reticulata* Spengler.

Semele spec.

Pl. 61, figs. 1, 4

Remarks.—There is a single incomplete right valve. The hinge is broken away except the posterior lateral tooth. The beaks must have been placed at about the center of the shell. Umbonal ridge inconspicuous. External sculpture consists of weak concentric threads. Radial element hardly visible even under a lens. This species has the dimensions and general outline of *S. sayi* Toulou (1909, p. 730, pl. 28, fig. 17), but its sculpture and umbonal ridge are less conspicuous. *S. quirosana* H. K. Hodson (*in* Hodson and Hodson, 1931a, p. 17, pl. 9, figs. 8, 12) from Quiroz is smaller and has a more prominent concentric sculpture. *S. firma* Pilsbry and Johnson (1917, p. 200) is of about the same size. The figure of the type given by Pilsbry (1922, pl. 46, fig. 10) is not clear enough to compare sculptural details.

Occurrence.—N.V.P. Blue No. 3892.

Family TELLINIDAE

Genus TELLINA Linné

Linné, 1758, *Systema Naturae*, ed. 10, p. 674.

Type species (by subsequent designation, Schmidt, C. F., *Versuch über die beste Einrichtung* . . . pp. 51, 177, Gotha, 1818), *Tellina radiata* Linné (see Gardner, 1943, U.S. Geol. Sur., Prof. Paper 199-A, p. 94).

Subgenus EURYTELLINA Fischer

Fischer, 1887, *Manuel de Conchyliologie*, p. 1147.

Type species (by monotypy), *Tellina punicea* Born.

Tellina (Eurytellina) paraguensis H. K. Hodson Pl. 61, figs. 2, 5, 6

1931. *Tellina (Moerella) paraguensis* H. K. Hodson, *in* Hodson and Hodson, *Bull. Amer. Paleont.*, vol. 16, No. 59, p. 12, pl. 5, figs. 5, 6, 11.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 24026.

Variability.—Though constant in outline it may be noted that the antero-dorsal slope, which generally is slightly curved, is straightened in some specimens. This causes a variably shaped curvature of the anterior margin. The pallial sinus may reach the anterior muscle scar, but mostly there remains a small distance between them.

Remarks.—The material consists of more than 60 single valves

of several growth stages. Length of largest specimen (G 11363): 32 mm. Many of the shells still retain some colour markings. There are a few concentric brownish bands of different width alternating with whitish to grayish interspaces. There is a large number of species of *Eurytellina*. The interior of several fossil forms is not known. Because the morphological differences often are slight, and because the base for comparative remarks consists of original descriptions and figures only, the following comparisons should be handled with care.

Comparisons.—*T. aequicincta* Spieker (1922, p. 158, pl. 10, fig. 3) from the Zorritos formation of Perú is somewhat larger than *T. paraguayensis*, more elongate, and has a less steep posterior slope. Its interior is not known. *T. amenensis* Olsson (1932, p. 122, pl. 13, figs. 2, 8) from the lower Miocene of Ecuador has the dimensions of *T. aequicincta*. Its general shape is practically identical with that of *T. paraguayensis*. But since its interior is not known, a further comparison is not possible. *T. cibaoica* Maury (1917, p. 223, pl. 38, fig. 10) from the upper Cercado formation of the Dominican Republic seems to differ by its less steep posterior slope. There are two other species which differ by a less steep posterior slope: *T. roburina* Dall (1900, p. 1024, pl. 47, fig. 9) from the Oak Grove sand of Florida, and *T. dariena* Conrad (1855, p. 18; Olsson 1922, p. 252, pl. 26, fig. 3) from the Gatún formation of the Panamá Canal Zone. There are a few specimens of the Recent type species of *Eurytellina*, *T. punicea* Born, from Trinidad at hand. This species is practically identical with *T. paraguayensis* in outline and differs only by its larger size. The Recent West Coast *T. mantaensis* Pilsbry and Olsson (1943, p. 80, pl. 8, figs. 1-4) has also a less steep postero-dorsal margin and differs in details of sculpture on the umbonal slope.

Occurrence.—N.V.P. Blue No. 3892, Re 1199.

Distribution.—Known from holotype locality only.

Genus **PSAMMACOMA** Dall

Dall, 1900, U.S. Nat. Mus., Proc. vol, 23, No. 1210, p. 292.

Type species (by original designation), *Tellina candida* Lamarck.

Psammacoma ? cf. **falconensis** H. K. Hodson

Pl. 61, figs. 3, 7

1931. *Macoma* (*Psammacoma*) *falconensis* H. K. Hodson in Hodson and Hodson, Bull. Amer. Paleont., vol. 16, No. 59, p. 16, pl. 6, figs. 1, 6, 7.

Remarks.— Besides a number of casts the material consists only of two single and partly broken valves. One of them (G 11365) has a well-preserved hinge. It is composed of two cardinals. The anterior one is moderately narrow and oblique, the posterior one triangular and bifid. Pallial sinus broad and rounded, not confluent with pallial line. The umbones lie but little behind the center of the shell. Since *Psammacoma* is mainly characterized by a short posterior slope, it is doubtful, whether or not this species belongs to it. The posterior slope of the holotype of Hodson's *P. falconensis* is shorter than that of the present specimens. In *Macoma gatunensis* Toulou (1909, p. 729, text-fig. 10), with which Hodson compared *P. falconensis*, this slope is even shorter and accentuated by a slight concavity.

The specimen described and figured by Barrios (1960, p. 262, pl. 7, fig. 12) as *Tellina* (*Angulus*) *democraciana* H. K. Hodson seems to belong into the morphological neighbourhood of *P. falconensis*.

Occurrence.— N.V.P. Blue No. 3892, Re 1148, Re 1154, Re 1155, Re 1199.

***Psammacoma* ? spec.**

Pl. 61, figs. 8-10

Shell large. Beaks situated little behind the center of the shell. Posterior slope straight. Anterior margin evenly rounded. Sculpture consists of incrementals only which become somewhat irregular behind the moderately accentuated umbonal ridge. Hinge of right valve composed of a small anterior cardinal and a heavier posterior cardinal. The latter is trigonal and divided into two about equal parts by a deep sulcus. Left anterior cardinal trigonal and slightly bifid but smaller than right posterior cardinal. Left posterior cardinal narrow, oblique. Ligamental area large, deeply sunken. Pallial sinus broad, angulated.

Remarks.— There are but three fragments of this species, the largest one (G 11366) measures 60 mm. in length. It seems to be premature to describe this form as new until better material is at hand. This species is larger than *Macoma* (*Psammacoma* ?) *democraciana* H. K. Hodson (in Hodson and Hodson 1931a, p.

15, pl. 6, figs. 3-5) from the upper middle Miocene of Falcón, and its anterior margin is more evenly rounded. These differences, however, may be shown to fall within the variability of *M. democraciana* by additional material.

Occurrence. — N.V.P. Blue No. 3892.

Family **CORBULIDAE**

Genus **CORBULA** Lamarck

Lamarck, 1799, Mém. Soc. Hist. Nat. Paris, p. 81.

Vokes, 1945, Am. Mus. Nat. Hist., Bull. vol. 86, art. 1, p. 7.

Type species (by subsequent designation, Schmidt, 1818, Versuch über die beste Einrichtung . . . , Gotha), *Corbula sulcata* Lamarck.

Subgenus **CARYOCORBULA** Gardner

Gardner, 1926, Nautilus, vol. 40, No. 2, p. 46.

Type species (by original designation), *Corbula alabamiensis* Isaac Lea.

Corbula (Caryocorbula) fortis, n. sp.

Pl. 62, figs. 1-6

Shell small. Right valve larger than left one. Right valve strongly produced posteriorly, more than left valve. Postero-ventral margin concave, ventral margin weakly curved, anterior margin evenly rounded. Postero-dorsal margin concave. Both valves strongly inflated. Umbonal ridge moderately prominent in young stages but subsequently becomes a conspicuous rounded elevated ridge. With increasing age a second or even a third rounded ridge are formed. They are distinguished from the rest of the surface by prominent growth lines. The left valves do not have these rounded ridges or only indications of them. Sculpture consists of somewhat irregular concentric ribs which become coarser towards the ventral margin.

Holotype. — Basel Natural History Museum, No. G 11369.

Dimensions of holotype. — Length 12.5 mm., height 7.6 mm., diameter 4.3 mm.

Variability. — The intensity and coarseness of the concentric ribs, and thus their number, is variable. The umbones are smooth. The sculpture may start with relatively broad and widely spaced ribs or with narrow and regular concentrics which are either widely spaced or close-set. A conspicuous change in sculpture may

occur, where the ventral portion of the shell turns into a direction, which is about perpendicular to the plane formed by the margin of the valve. Many right valves show, in addition to the umbonal ridge of the younger stages, a second less prominent ridge, which is the continuation of the uppermost rounded ridge of the later stages.

Remarks.—The hinge and pallial features of the rich material at hand are the same as those shown for *C. alabamiensis* Lea by Stenzel, Krause, and Twining (1957, p. 166, fig. 27). The right valves are much better represented in the studied material than the left valves. The bipartite chondrophore of the left valves is not conspicuous and rarely well preserved.

Paratypes have been sent to the British Museum (Natural History), the Paleontological Research Institution, Ithaca, New York, and the U.S. National Museum, Washington, D.C.

Comparisons.—The pointed posterior production of the right valve is the distinguishing feature of this species. It is slightly indicated in *C. collazica* Maury (1920, p. 44, pl. 6, figs. 10, 11) and the Recent West Coast *G. nasuta* G. B. Sowerby I (1833, p. 35; Olsson 1961, p. 429, pl. 75, figs. 3-3e). According to the original figure, a left valve, *C. propinqua* Spieker (1922, p. 174, pl. 10, fig. 16) seems to be less inflated, and its antero-dorsal margin less steep.

Occurrence.—N.V.P. Blue No. 3892, Re 1199.

Corbula (Caryocorbula) quirosana F. Hodson

Pl. 62, fig. 7.

1931. *Corbula (Caryocorbula) quirosana* F. Hodson, in Hodson and Hodson, Bull. Amer. Paleont., vol. 16, No. 59, p. 25, pl. 9, figs. 10, 11, 13-18.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 24056.

Remarks.—There is a single left valve of this species. The shell is unusually delicate for a *Corbula*. The widely spaced radial threads, which are best developed on the anterior portion, are just observable on the top of the concentric waves but are more prominent in the interspaces.

Comparisons.—The shell strikingly resembles *C. viminea* Guppy (1866a, p. 293, pl. 18, fig. 11) from Bowden, Jamaica, the type species of *Bothrocorbula*. It has the same general outline and sculptural pattern, but it lacks the diagnostic feature of *Bothrocorbula*: the deep lunular depression. *C. guaiconensis* Maury (1925,

p. 110, pl. 19, figs. 13, 14, 18) from the Machapoorie Miocene of Trinidad, which has been assigned to *Bothrocorbula*, does not show the lunular depression, and, therefore, is a *Caryocorbula*. It has a similar sculpture but is larger. *C. hexacyma* Brown and Pilsbry (1913, p. 518, pl. 26, fig. 4) from the Gatún formation of the Panamá Canal Zone is much larger and of heavier appearance.

Occurrence.—N.V.P. Blue No. 3892.

Distribution.—"Miocene" of Falcón and Zulía, Venezuela.

Subgenus **TENUICORBULA** Olsson

Olsson, 1932, Bull. Amer. Paleont., vol. 19, No. 68, p. 141.

Type species (by original designation), *Corbula tenuis* G. B. Sowerby I.

Corbula (Tenuicorbula) aff. tenuis lupina Olsson Pl. 62, figs. 8, 9

1932. *Corbula (Tenuicorbula) tenuis lupina* Olsson, Bull. Amer. Paleont., vol. 19, No. 68, p. 143, pl. 14, figs. 7, 10.

Remarks.—There is a single right valve of this species. The secondary keel on the posterior slope defining an escutcheon-like area is not developed, and in this respect the shell is not a typical *Tenuicorbula*. But the coarse sculpture on the posterior area disappears at a small distance from the postero-dorsal margin, thus leaving an ill-defined escutcheon-like area with weak surface markings. More material would perhaps show that the secondary keel varies in strength. In this case the shell would represent the extreme of the variability of one feature.

Comparison.—The shell chiefly differs from *C. tenuis lupina* Olsson from the Tumbes formation of Perú by its more produced posterior end. In addition it is smaller and does not show the slight concavity at about the center of the ventral margin. The Recent West Coast *C. tenuis* G. B. Sowerby I (1833, p. 36; Olsson 1961, p. 434, pl. 77, figs. 3, 3a) (= *C. glypta* Li) is even less produced posteriorly than *C. tenuis lupina*. The sculpture on the posterior slope is much coarser on this shell. Other *Tenuicorbula*s are discussed by Olsson (1932, pp. 141-145). The present shell shows more affinities to the Recent West Coast *C. tenuis* with its posterior production than to the Recent Caribbean *C. aequivalvis* Philippi (1836, Arch. für Naturg., vol. 2, Teil 1, p. 227) which is not produced posteriorly.

Occurrence.—N.V.P. Blue No. 3892.

Class GASTROPODA

Family ACMAEIDAE

Genus ACMAEA Eschscholtz

Eschscholtz, 1830 in Kotzebue Neue Reise um die Welt in den Jahren 1823, 24, 25 und 26, vol. 2, Appendix, p. 24.

Type species (by subsequent designation, Dall, 1871, Amer. Jour. Conch., vol. 6, pt. 3, p. 238), *Acmaea mitra* Eschscholtz.

Acmaea ? astroides, n.sp.

Pl. 62, figs. 10, 11

Shell small, moderately high. Base oval. Apex situated a little in front of the center. Radial sculpture strong. Primary ribs narrow, but high, extending over the margin of the shell. Between the primaries there are one or two secondaries slightly varying in size. Sometimes tertiary ribs are intercalated. Growth lines close set not conspicuous. Inner margin of shell crenulated. Situation of muscle attachment area not recognizable.

Holotype.—Basel Natural History Museum, No. H 13635.

Dimensions of holotype.—Length 12.0 mm., width 9.0 mm., height 4.3 mm.

Remarks.—There are two shells which apparently represent this new species. A third shell (H 13637), which is rolled and larger (length 17.2 mm.), is tentatively assigned to this species. Its muscle impression is different to that of an *Acmaea*. The opening of this "horseshoe-shaped" impression does not lie on the anterior part of the shell but on the posterior left side. On the holotype and the only paratype (H 13636) the characters of the muscle impression are not recognizable, so that their attribution to *Acmaea* is questionable.

Comparisons.—*A. acra* Woodring (1928, p. 459, pl. 40, figs. 13-15) from the Bowden formation of Jamaica is more circular in outline. The radial ribs do not extend over the margin and are less strong. The Recent *A. atrata* Carpenter (see Palmer, 1958, p. 122) from Lower California has a similar intensity of sculpture but is larger (for a figure see Keen, 1960, p. 243).

Occurrence.—N.V.P. Blue No. 3892.

Family **NERITIDAE**Genus **NERITA** Linné

Linné, 1758, *Systema Naturae*, ed. 10, p. 776.

Type species (by subsequent designation, Montfort 1810, *Conchyliologie systématique*, vol. 2, p. 347), *Nerita peloronta* Linné.

Subgenus **NERITA** s.str

The following species belongs to *Nerita* s.str. according to Russell (1941, p. 357). It might be attributed also to *Theliostyla* Mörch (see Wenz, 1938, *Handbuch der Paläozoologie*, Bd. 6, p. 420), the features of the parietal region lying between the definitions of both subgenera.

Nerita (Nerita) fulgurans Gmelin

Pl. 62, fig. 14

1791. *Nerita fulgurans* Gmelin, *Systema Naturae*, vol. 1, pt. 6, p. 3685.

1941. *Nerita (Nerita) fulgurans* Gmelin, Russell, *Bull. Mus. Comp. Zool.*, vol. 88, No. 4, p. 363, pl. 1, figs. 5, 6.

1954. *Nerita fulgurans* Gmelin, Abbott, *American Seashells*, p. 129, pl. 4c.

1958. *Nerita fulgurans* Gmelin, Coomans, *Studies on the fauna of Curaçao and other Caribbean Islands*, vol. 8, No. 31, p. 60, pl. 7, (2 figs.).

1962. *Nerita fulgurans* Gmelin, Warmke and Abbott, *Caribbean Seashells*, p. 50, pl. 9i.

Remarks.—A good description of this species, together with radular and ecological data, is found in Russell (1941, p. 363). There are two characteristics which differ somewhat from this description, its accompanying figures and one Recent specimen from Tobago at hand: the two teeth on the columella are stronger, and the two uppermost denticles and the lowermost one on the outer lip are stronger too. The parietal region of the shells from Paraguaná is slightly less concave than that of the specimen from Tobago. The colour pattern of the material is not preserved. There are two specimens from near Puerto Lopez, Guajira Peninsula, from beds of upper Pliocene or even Peistocene age, which have retained a faded colour pattern. The pattern is practically identical with that of the Recent shell.

Trechmann (1935, p. 551, pl. 20, fig. 30) described *N. exuvioides* from Carriacou from beds of questionable Pliocene age. Russell (1941, p. 355) stated that there are no living representatives of the West Indian fossil. The differences between Recent

and fossil shells mentioned above do not seem sufficient for sub-specific or even specific separation.

Comparisons.—The differences between *N. fulgurans* and *N. tessellata* Gmelin have been pointed out by Russell (1941, p. 364).

Occurrence.—N.V.P. Blue No. 3892, Re 1155.

Distribution.—Recent, West Indies (see distribution map in Russell, 1941, pl. 6, fig. 1). Beds of upper Pliocene or Pleistocene age near Puerto Lopez, Guajira Peninsula.

Genus **NERITINA** Lamarck

Lamarck, 1816, Encycl. Méthodique, Vers, vol. 3, pl. 455; Liste p. 11.

Type species (by subsequent designation, Children, 1823, Lamarck's genera of shells, p. 111), *Nerita pulligera* Linné.

Neritina aff. **woodwardi** Guppy

Pl. 62, figs. 12, 13

1866. *Neritina woodwardi* Guppy, Quart. Jour. Geol. Soc. London, vol. 22, p. 291, pl. 18, figs. 4, 5.

Shell small. Spire low. Whorls about $3\frac{1}{4}$. Last whorl greatly inflated. Colour pattern consisting of broad dark "opisthocline" bands, which are somewhat wavy, separated by narrower bright bands. Area just below suture slightly impressed. Columellar lip with a few weak centrally placed denticles.

Remarks.—There is a single well-preserved shell, which may represent *N. woodwardi*. *N. woodwardi* has been redescribed and refigured by Woodring (1928, p. 424, pl. 35, figs. 7-9). The specimen, which has dimensions comparable to those of Woodring's figured shells, is probably adult. Its denticles on the inner lip have not disappeared. Woodring's description of the colour pattern does not agree with that of this shell.

Comparisons.—Woodring compared *N. woodwardi* with the Recent *N. punctulata* Lamarck which has a different colour pattern than this shell. The colour pattern of the specimen agrees perfectly with that of *N. virginica* Linné figured by Coomans (1958, pl. 7, figure at right bottom). *N. virginica* is said to have an extreme variability of colour patterns (Russell 1941, pp. 375-376). A rich material of this species at hand shows that it has a consistently higher spire.

Occurrence.—N.V.P. Blue No. 3892.

Family **TURRITELLIDAE**

Genus **TURRITELLA** Lamarek

Lamarek, 1799, Soc. Hist. Nat. Paris, Mém., vol. 1, p. 74.

Type species (by monotypy), *Turbo terebra* Linné.

Turritella cocoditana F. Hodson

Pl. 63, figs. 1-6

1926. *Turritella berjadinensis cocoditana* F. Hodson, Bull. Amer. Paleont., vol. 11, No. 45, p. 29, pl. 19, fig. 5; pl. 20, figs. 3, 7, 10.

Protoconch consists of nearly two entire smooth volutions. Primary spiral ornamentation tricostrate: a median to submedian accentuated rib, a second one nearly at the base of the whorl, and a third faint one on the upper half of the whorl. On adolescent whorls a secondary spiral appears between the suture and the lowest primary, which, on adult whorls, develops into a wide basal flange just behind the suture. The upper two primaries often become nodulous but only on a few volutions. Many secondary and then tertiary spiral threads appear over the whole surface of the whorl during the adolescent stage. The predominant median spiral of the adolescent stage becomes relatively smaller compared with the basal flange of the adult whorls, which, here, is overhanging the deeply constricted upper half of the next whorl. The base of the whorls carries several secondary spirals with tertiary intervening threads. The growth lines are prosocline on the constricted part of the whorl but then turn into an orthocline direction. When crossing the basal flange they become slightly prosocline again. Apical angle not constant.

Holotype. — Pal. Res. Inst., Ithaca, New York, No. 21487.

Variability. — The rich material at hand shows that this species is strongly variable. If one picks out a few sculptural elements, one can observe that they may be variously developed in corresponding ontogenetic stages of different specimens. The variability is demonstrated to some degree by the illustrations of this species.

Remarks. — The gerontic stage is characterised by conspicuous growth lines and rounded whorls. The spiral sculpture often becomes indistinct and obscure. The form of the growth lines is practically the only feature which is constant throughout.

Woodring (1957, p. 110) mentioned a whorl fragment from the Culebra formation (early Miocene) from the Panamá Canal Zone, which he tentatively referred to *T. cocoditana*.

The other subspecies of *T. berjadinensis*, which Hodson described together with *T. cocoditana* (*berjadinensis* s.str., *colinensis*, *socorroensis*, *warfieldi*) partly represent different forms.

Comparisons.—The typical form of *T. cocoditana* is unique. *T. alcida* Dall (1896, p. 23; Gardner, 1947, pl. 57, fig. 2) and *T. alcida bicarinata* Gardner (1947, p. 592, pl. 57, fig. 3), both confined to the Oak Grove sand of Florida, are much larger species and hardly comparable with *T. cocoditana*. The sutures of *T. berjadinensis* are never so deeply incised, and the areas between the main sculptural elements less concave. The earliest stages of *T. berjadinensis* are not known. Some variations of *T. cocoditana* show a certain resemblance with the late whorls of *T. gatunensis* Conrad (1857, p. 72, pl. 5, fig. 20; Woodring 1957, p. 108, pl. 23, figs. 4, 5, 9, 14), but the first sculpture of this species is different.

Occurrence.—N.V.P. Blue No. 3892, Re 1148, Re 1152, Re 1153, Re 1154, Re 1155, Re 1193, Re 1199.

Distribution.—Recorded from the La Rosa formation (lower Miocene) of the Maracaibo Basin by Sutton (1946, p. 1696).

Turritella machapoorensis paraguaneis F. Hodson Pl. 63, figs. 9, 10

1931. *Turritella machapoorensis paraguaneis* F. Hodson, in Hodson and Hodson, Bull. Amer. Paleont., vol. 16, No. 60, p. 9, pl. 8, fig. 1.

Protoconch missing. First sculptured whorls with two primary spiral ribs dividing the volution into two lower, about equally spaced concave areas and a narrower uppermost part with straight profile. In the adolescent stage the base of the whorl becomes swollen. This swelling increases on subsequent volutions, until it forms a basal rib slightly overhanging the appressed suture. In adult stages it carries minute spiral striae. The primaries of the early whorls show but a weak development with increasing age and are of secondary size only or even tend to disappear among tertiary threads of varying strength, by which the whole surface of the adult whorls is covered. The profile of the whorls is nearly straight in young stages but regularly concave on adult whorls. The growth lines form a deep antispiral sinus with its maximum lying about on the middle of the whorl.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 24141.

Remarks.—The features of this form are constant. Whether

these specimens are a subspecies of *T. machapoorensis* Maury (1925, p. 234, pl. 42, fig. 11) or an independent species, is difficult to decide, because Maury's figure is poor. The figure given by Mansfield (1925, pl. 7, fig. 10) shows a specimen greatly diverging from ours.

Comparisons.—I have examined an European shell (H 9452) with the following label: *Turritella strangulata* Grateloup, lower Tongrien, Lesbarritz near Gaas, Gironde, 1857). This *Turritella* resembles the specimens studied more than any other American species (see Pl. 63, fig. 11). The European shell has a less pronounced ribbing. Its basal spiral carries tertiary threads and is crossed by conspicuous growth lines. *T. machapoorensis guarirensis* F. Hodson (in Hodson and Hodson, 1931b, p. 10, pl. 7, fig. 5; pl. 8, fig. 3) has two basal spirals, and the somewhat noded spirals of the adult whorls separate it distinctly from the present material. The description of *T. collazica* Maury (1920, p. 51, pl. 8, fig. 5) is based on an internal mold only. Its adult whorls are less concave. *T. bowenae* Mansfield (1937a, p. 166, pl. 9, fig. 3) from the Suwannee limestone of Florida has a straight whorl profile, but a spiral ribbing similar to that of the present form. The primary ornamentation of the first sculptured whorls seem to be the same.

Occurrence.—N.V.P. Blue No. 3892, Re 1154.

Distribution.—Known from type locality only.

Turritella machapoorensis wiedenmayeri F. Hodson Pl. 62, figs. 15, 16

1931. *Turritella machapoorensis wiedenmayeri* F. Hodson, in Hodson and Hodson, Bull. Amer. Paleont., vol. 16, No. 60, p. 9, pl. 7, figs. 1-4.

Protoconch missing. First sculptured whorls as in *T. machapoorensis paraguayensis*. The lower primary becomes about equal in size as the basal spiral. Already in young stages a weak rib appears between them which is of primary size on adult whorls. Whole surface of whorl ornamented by regularly spaced secondary ribs with intercalated tertiary threads. Growth lines as in *T. machapoorensis paraguayensis*.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 24137.

Variability.—Two factors undergo a certain variation: the concavity of the whorls and the intensity of the spiral sculpture.

Remarks.—If *T. machapoorensis paraguayensis* should prove

to represent an independent species, *T. machapoorensis wiedenmayeri* should be considered as a subspecies of it, because the primary sculpture of both forms has the same origin. Only the degree of its development is different producing many intermediate forms.

Occurrence.— N.V.P. Blue No. 3892, Re 1148.

Distribution.— Recorded from State of Falcón only.

***Turritella gilbertharrisi* F. Hodson**

1926. *Turritella gilbertharrisi* F. Hodson, Bull. Amer. Paleont., vol. 11, No. 45, p. 17, pl. 12, figs. 2, 4, 6; pl. 13, figs. 1-6; pl. 14, figs. 1, 4, 7.

? 1931. *Turritella gilbertharrisi* Hodson, Olsson, Bull. Amer. Paleont., vol. 17, No. 63, p. 77, pl. 13, figs. 5, 6, 7, 11, 12; pl. 14, fig. 1.

Holotype.— Pal. Res. Inst., Ithaca, New York, No. 21436.

Remarks.— There is a single fragment (H 13650) (three adult whorls) referable to this species. The straight whorl profile is characteristic for this *Turritella* and its subspecies. *T. hubbardi* Hodson (1926, p. 14, pl. 7, figs. 2-5; pl. 8, figs. 1-6; pl. 9, figs. 1, 5, 6) has the two anterior primaries much more prominent and generally strongly noded. *T. indenta mixta* Dall (1892, p. 309; Gardner 1947, p. 596, pl. 57, fig. 7), a similar species from the Chipola formation of Florida, does not show the secondary spiral between the uppermost primary and the posterior suture.

Occurrence.— Re 1155.

Distribution.— "Oligocene-Miocene" of the states of Falcón and Zulia, Venezuela. The record from the Chira formation of Peru is questionable.

***Turritella matarucana* F. Hodson**

Pl. 63, fig. 7

1926. *Turritella matarucana* F. Hodson, Bull. Amer. Paleont., vol. 11, No. 45, p. 31, pl. 20, fig. 4, pl. 21, figs. 1, 9.

1926. *Turritella plebeia A-L-Owensi* F. Hodson, Bull. Amer. Paleont., vol. 11, No. 45, p. 31, pl. 20, figs. 1, 2, 5, 6, pl. 23, fig. 2, pl. 28, fig. 1.

1957. *Turritella matarucana* Hodson, Woodring, U.S. Geol. Sur., Prof. Paper 306-A, p. 107, pl. 22, figs. 11, 12.

Nucleus and first sculptured whorls missing. The early preserved whorls carry a spiral rib on the anterior third marking a keel, and halfway between it and the posterior suture there is another spiral. A third but less conspicuous one lies between the keel and the anterior suture. The sculpture of the next two or three volutions consists of four equally spaced spirals above the keel and

two close-set lirae near the posterior suture. In the following stages many additional spirals appear on the whole surface of the whorl. Correspondingly the basal keel gradually becomes less prominent. The spirals are of different size and tend to be broad and partly close-set. Profile of adult whorls somewhat convex. Suture furrowed. Base ornamented by spiral threads which are indistinct near center. Sinus of growth lines not deep. Growth line angle wide.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 21512.

Comparisons.—The reasons for the synonymy of *T. plebeia allowensi* are given by Woodring (1957, p. 107). The original figure of *T. plebeia* Say (1824, pl. 7, fig. 1) shows a similar sculpture, but the whorls are much more rounded, and the sutures deeply furrowed. *T. andreasii* Hodson (1926, p. 37, pl. 24, figs. 7-9, 12, pl. 25, fig. 2) has less spirals on the adult whorls with wider interspaces, and the whorls are more inflated. The sculpture, growth lines, and general appearance of *T. fica* Olsson (1932, p. 195, pl. 22, figs. 3, 9) from the lower Zorritos formation of Perú are similar to *T. matarucana*, but the slight concavity on the upper half of the volution is never observable in this material. The similarity with *T. wittichi* Hertlein and Jordan (1927, p. 635, pl. 21, figs. 3, 4) from the Miocene of Lower California is striking. The suture, however, is slightly less furrowed than in *T. matarucana*. *T. pre-nuncia* Spieker (1922, p. 81, pl. 4, figs. 1-3) from the Zorritos formation of Perú shows about the same profile but carries only five primaries which are accentuated and have relatively wide interspaces.

Occurrence.—N.V.P. Blue No. 3892, Re 1148, Re 1199.

Distribution.—See Woodring (1957, p. 108).

***Turritella* cf. *venezuelana* F. Hodson**

Pl. 63, fig. 8

1926. *Turritella venezuelana* F. Hodson, Bull. Amer. Paleont., vol. 11, No. 45, p. 32, pl. 21, figs. 4, 8; pl. 22, figs. 1, 6.

Remarks.—Only three specimens of this form are at hand. One of them (H 13652) shows on its first preserved whorls two strong submedian primaries. Above the upper primary the whorl profile is straight. The suture is overhung by the steep and narrow slope in front of the lower primary. On the following volution three secondary spirals appear: the lowest one between the lower primary and the anterior suture, the second one between the two

primaries, and the third one between the upper primary and the posterior suture. Soon all the spirals on the whorl become equal in size, thus showing the following typical pattern on the adolescent whorls: four spirals with concave interspaces on the wide upper portion (the interspace between the two uppermost ribs in general being somewhat larger than the others), and one spiral on the steep and narrow anterior slope. Just below the posterior suture two weak and close-set spirals appear which develop less rapidly than the others. In later stages tertiary threads are intercalated between some of the spirals and the carina formed by the lower primary tends to disappear.

Comparisons.—Adult whorls resemble those of *T. matarucana*, and also the growth lines with their shallow sinus are nearly identical. The lower portion of the whorl of *T. matarucana* is more rounded, and the entire whorl carries more spirals. On the other hand this material resembles much more Hodson's two subspecies *T. venezuelana quirosana* (1926, p. 34, pl. 22, figs. 9, 10; pl. 24, fig. 1) and *T. venezuelana watkinsi* (*idem*, pl. 22, fig. 8) which are put in the synonymy of *T. venezuelana* by Woodring (1957, p. 106).

Occurrence.—N.V.P. Blue No. 3892, Re 1199.

Family ARCHITECTONICIDAE

Genus ARCHITECTONICA Röding

Röding 1798, Museum Boltenianum, pt. 2, p. 78.

Type species (by subsequent designation, Gray, 1847, Zool. Soc. London, Proc., pt. 15, p. 151), *Trochus perspectivus* Linné.

Subgenus ARCHITECTONICA s.str.

Architectonica (Architectonica) nobilis nobilis Röding Pl. 64, figs. 1-7

1798. *Architectonica nobilis* Röding, Museum Boltenianum, p. 78.

1959. *Architectonica (Architectonica) nobilis nobilis* Röding, Woodring, U.S. Geol. Sur., Prof. Paper 306-B, p. 165, pl. 29, figs. 1-6, 10-12, 14-16. For additional citations see this publication.

1960. *Architectonica (Architectonica) nobilis quadriseriata* (G. B. Sowerby I), Perrilliat Montoya, Paleontologia Mexicana, No. 8, p. 18, pl. 3, figs. 4, 5.

1960. *Architectonica granulata* (Lamarck), Barrios, Bol. Geol., vol. 6, Nos. 1-3, Informe No. 1082, p. 268, pl. 8, figs. 5, 6.

1961. *Architectonica (Architectonica) nobilis nobilis* Röding, Pflug, Acta Humboldtiana, ser. geol. et pal., Nr. 1, p. 17, pl. 1, figs. 1-7.

1962. *Architectonica nobilis* Röding, Weisbord, Bull. Amer. Paleont., vol. 42, No. 193, p. 152, pl. 13, figs. 15, 16.

Nuclear whorls visible on dorsal surface consisting of one volution. First sculpture not developing slowly but starting abruptly. Dorsal sculpture composed as a rule of four spirals and a peripheral keel on each whorl. The peripheral keel or cord may be covered, at least partly, by the succeeding whorl. Its sculpture varies from smooth to closely beaded. It is generally better separated from the four spirals than these are among themselves. In younger stages the four spirals are more or less closely granulated. With increasing age the granulation generally flattens or may almost disappear. The lowest and the uppermost of the four spirals, however, are mostly the last ones to lose their sculpture, either both together or only one of them. The interspace between the second and third spiral tends to become indistinct and may, in rare cases, disappear. The whorls as a whole are flat to slightly convex. The base of the shell is flat to slightly convex. Umbilicus moderately wide. The sculpture of the base consists of six spirals. Beginning from the center the first spiral is rather thick carrying about a dozen radially elongate nodes (in an adult volution). The second spiral is narrower, ornamented by numerous closely set nodes, and flanked on either side by a conspicuous relatively deep furrow. The third carries about the same number of nodes which are less conspicuous. Third and fourth spirals are separated by a weak incised line. The fourth and fifth are almost smooth except for fine radial lines. Their interspace is only finely marked or may disappear. The sixth is clearly noded again and well separated from the fifth spiral and the peripheral cord.

Remarks. — The variability of the intensity of sculpture of this species is partly contained in the above description. It has also been mentioned by Rutsch (1934, p. 43) and Woodring (1959, p. 166). Woodring (*idem*) discussed the occurrence of a secondary spiral between the peripheral cord and the next dorsal spiral and a correspondingly situated one on the ventral side of the shell. None of the 57 specimens from Paraguaná shows this secondary spiral. It is present, however, on specimens from Punta Gavilán, Bowden, and Banana River (Costa Rica) at hand. The specimen from Costa Rica differs from others in having wider interspaces dorsally and ventrally and correspondingly narrower spirals. A specimen from Punta

Gavilán has a maximum diameter of 59 mm. The present shells never reach this size, the largest one (H 13660) measuring only 25.9 mm. in diameter. Recent specimens possess the secondary spiral ventrally and dorsally (Dominican Republic, Coast of Texas) or only ventrally (Barbados). Specimens of *A. perspectiva* (Linné), the type species, show it on both sides.

Comparisons.—Grant and Gale (1931, p. 786, pl. 32, figs. 27a, b) described *A. nobilis discus* from the Pliocene of California and Mexico. They stated that it differs from *A. nobilis s.str.* by "a sharper basal periphery," but added below that it "differs surprisingly little from the Recent form." Their figures are not clear enough to give any comparative remarks. It should probably be attributed to *A. nobilis s.str.* *A. alvear* Gardner (1936, p. 48, pl. 9, fig. 2, pl. 10, figs. 5, 6) from the Oak Grove sand of Florida has less spirals on the ventral side than *A. nobilis s.str.* On the dorsal side the upper three spirals are indistinctly separated from each other and, except of oblique growth lines, smooth even in young stages. Only the lowest spiral and the peripheral keel are strongly noded, thus causing a regular rhythm of sculptural changes from the apex to the periphery. The same difference shows *A. amphiterma* (Dall) (1892, p. 330, pl. 22, figs. 16, 16a). Its ventral side has even less spirals than *A. alvear*. *A. almagrensis* (Böse) (in Böse and Toulia, 1910, p. 224, pl. 12, fig. 4) seems to have a lower ratio of height to diameter, and the dorsal surface is flat. The umbilical keel is narrower than in *A. nobilis s.str.* and the protoconch larger (in this respect approaching the subgenus *Psilaxis*).

Occurrence.—N.V.P. Blue No. 3892, Re 1148, Re 1152, Re 1154, Re 1155, Re 1199.

Distribution.—See Woodring (1959, p. 167).

Architectonica (Architectonica) nobilis karsteni Rutsch Pl. 64, figs. 8-10

1934. *Architectonica nobilis karsteni* Rutsch, Abh. Schweiz. Pal. Ges., Bde. 54 & 55, p. 44, pl. 1, figs. 8-10.

? 1935. *Solarium gatunense* Toulia, Trechmann, Geol. Mag., vol. 72, No. 858, p. 549, pl. 21, figs. 21, 22.

1951. *Architectonica sexlinearis haughti* Marks, Bull. Amer. Paleont., vol. 33, No. 139, p. 93, pl. 2, figs. 2, 6.

1959. *Architectonica (Architectonica) nobilis karsteni* Rutsch, Woodring, U.S. Geol. Sur., Prof. Paper 306-B, p. 167, pl. 30, figs. 1-3.

The two middle of the four original dorsal spirals fused to-

gether and mostly ornamented by oblique wrinkles or lines. Their (central) interspace sometimes slightly indicated. Lowest spiral mostly closely noded; uppermost one may be less distinct. Ventral sculpture consisting centrally of a coarsely noded umbilical cord bordered outwards by a distinct groove. The following broad band is smooth except for more or less accentuated wrinkles. It is succeeded outwards by a narrow closely noded spiral. The peripheral cord again is coarsely noded. A secondary spiral next to the peripheral cord is frequently indicated on the ventral but rare on the dorsal side.

Holotype.—Basel Natural History Museum, No. H 1836.

Remarks.—The above description is based on 19 specimens. It agrees in the main diagnostic character with the original description (a single conspicuous spiral groove next to the umbilical keel). The dorsal sculpture, however, is not identical with that of the holotype which is at hand. The four dorsal spirals, typical for *A. nobilis s.str.*, are well discernible on the type material, whereas on the present material the two middle ones are fused. In this respect these specimens resemble Woodring's material from the Chagres sandstone (early Pliocene) of the Panamá Canal Zone, and the specimens from Tecolotepec (Coatzacoalcos River, Isthmus of Tehuantepec) mentioned by Rutsch (1934, p. 44) and Woodring (1959, p. 168). The secondary spirals on the ventral side next to the peripheral cord, frequently indicated on this material, are not observable on the type material. Woodring interpreted this subspecies as representative of a tendency towards suppression of sculpture. As far as the dorsal sculpture is concerned this interpretation may be adopted, but the presence of secondary spirals on the ventral side does not support this view.

Comparisons.—As mentioned by Rutsch (1934, p. 44) one specimen figured by Böse (1906, pl. 3, figs. 6, 7) as *A. villarellói* is this subspecies. *A. amphiterma* (Dall) (1892, p. 330, pl. 22, figs. 16, 16a) has a dorsal sculpture similar to that of these specimens, but the ventral side shows two distinct grooves bordering the second spiral from the center.

Occurrence.—N.V.P. Blue No. 3892, Re 1148, Re 1199.

Distribution.—See Woodring (1959, p. 168).

Family **POTAMIDIDAE**Genus **POTAMIDES** Brongniart

Brongniart, 1810, Ann. Mus. Hist. Nat. (Paris), vol. 15, pp. 367, 368.

Type species (by monotypy), *Potamides lamarchii* Brongniart.

Potamides suprasulcatus (Gabb)

Pl. 64, figs. 11, 12

1873. *Cerithium suprasulcatum* Gabb, Amer. Philos. Soc., Trans., new ser., vol. 15, p. 237.

1917. *Potamides ormei* Maury, Bull. Amer. Paleont., vol. 5, No. 29, p. 126, pl. 22, fig. 8.

1959. *Potamides suprasulcatus* (Gabb), Woodring, U.S. Geol. Sur., Prof. Paper 306-B, p. 176, pl. 28, figs. 3-6. For additional citations see this publication.

Shell of medium size. Apical angle large. Profile of whorls flat, at least in young stages. Last whorls somewhat convex. Protoconch missing. Spiral sculpture consists of two bands, the anterior one nearly twice as large as the posterior one. These are ornamented by axially elongate nodes set off along the separating groove. This groove between the two bands is inconspicuous on early whorls, the nodes being separated axially by a shallow depression only. But subsequently this groove becomes deep. With increasing age a faint spiral groove appears on the anterior band separating it into two equal parts. Thus on adult whorls there are three spiral rows of squarish nodes, the posteriormost being somewhat larger, and a fourth just appearing posterior to the suture. On the last whorl there are 13 spiral cords in all, the anterior ones being less nodose. Outer and inner lips thick. Siphonal canal short and oblique. Inner lip partly detached from wall of shell and thickened posterior to siphonal canal. Posterior canal conspicuous. Inner surface of outer lip carrying four denticles on its upper part, the posteriormost of them being the largest and longest. An additional swelling is present just posterior to the siphonal canal.

Type.—Acad. Nat. Sci., Philadelphia, No. 1314.

Remarks.—There is a single fragment of five whorls (H 13665) of a young individual. Its first whorl has the nodes of the two spiral bands connected. Its last preserved whorl shows a faint groove on the anterior band. The columella is smooth. The description of the apertural features is based on a well-preserved specimen from near Puerto Lopez, Guajira Peninsula. Its aperture

is figured here (Pl. 64, fig. 11) to complete Hedberg's figures (1937, pl. 8, figs. 10, 11).

Comparisons.—Comparisons with similar forms have been given by Woodring (1959, p. 177).

Occurrence.—N.V.P. Blue No. 3892.

Distribution.—See Woodring (1959, p. 177). Additional record: middle Miocene beds near Puerto Lopez, Guajira Peninsula.

Family **CERITHIIDAE**

Genus **RHINOCLAVIS** Swainson

Swainson, 1840, A treatise on malacology, p. 315.

Type species (by subsequent designation, Herrmannsen, 1848, *Indicis* generum malacozoorum, vol. 2, p. 392), *Cerithium vertagus* (Linné).

Subgenus **OCHETOCLAVA** Woodring

Woodring, 1928, Carnegie Inst. Wash. Pub. 385, p. 334.

Type species (by original designation), *Cerithium gemmatum* Hinds.

Rhinoclavis (Ochetoclava) venada (Maury) Pl. 64, figs. 13, 14

1925. *Clava venada* Maury, Bull. Amer. Paleont., vol. 10, No. 42, p. 222, pl. 41, fig. 10.

Shell of medium size. Apical angle relatively large. Profile of whorls flat. Protoconch missing. Earliest preserved whorls ornamented by axial ribs. Subsequently a spiral sculpture consisting of three ribs is superimposed. Nodes are formed at the intersection points. On succeeding whorls secondary spirals are intercalated, and the axials become inconspicuous in the interspaces. In late stages tertiary threads appear between primary and secondary ribs. Spirals are narrower than their interspaces. The posteriormost of the three spirals somewhat wider than the others, its nodes being larger also. On the last or even on the penultimate whorl the nodes of the posteriormost spiral develop into spines projecting at about right angles from the main shell axis. Varices moderately prominent. Inner lip detached from pillar. Outer lip broken. Posterior canal reaching up to the middle portion of the preceding whorl, its inner surface bearing a groove for some distance. Columella with a conspicuous medial fold and a second less prominent one bordering the siphonal canal.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 1086.

Remarks.—There are eight specimens of this species. It is questionable, whether the development of spines on the uppermost spiral of the last whorl has to be considered as a feature of variability or not. The intercalated spiral tertiary threads probably are of less importance. They are also observed on specimens from the uppermost Caujarao formation of the LaVela area. But those shells never show the above mentioned spines. The specimens from Trinidad at hand also do not have these spines. A single, not a mature shell (H 13676) from near Brasso Venado, *i.e.* from near the type locality, shows a few spines on its last whorl. Further material from both, the type locality and Paraguaná, will show whether the form from Paraguaná has to be treated as a subspecies of *R. venada* or not.

Comparisons.—Woodring (1928, p. 335), in his key to the Bowden species of *Ochetoclava*, distinguished between a group with coarse and another group with fine sculpture including *O. terpna*. The material belongs to the latter. *R. terpna* (Woodring) (1928, p. 336, pl. 25, fig. 9) differs from *R. venada* by its much smaller size, its more prominent varices, the absence of tertiary spiral threads, and its convex whorls. The other group embraces *R. costaricana* and its subspecies. One specimen of *R. costaricana* (Olsson) (1922, p. 144, pl. 10, figs. 3, 4) from the type locality at hand shows a much coarser spiral sculpture than *R. venada*. The spirals are wider than their interspaces and carry axially elongate nodes. The axials sometimes are visible even in the interspaces. There are no tertiary threads and no spines. *R. costaricana stena* (Woodring) (1928, p. 335, pl. 25, figs. 7, 8) from Bowden, Jamaica, and *R. costaricana canabina* Woodring (1959, p. 171, pl. 38, figs. 1, 2) from the Gatún formation of the Panamá Canal Zone have been compared with morphologically related forms by Woodring. *R. plebeia* (G. B. Sowerby I) (1850, p. 51) from the Miocene of the Dominican Republic seems to differ from *R. venada*, according to Maury's figures (1917, pl. 9, fig. 8), mainly by its larger apical angle and the somewhat convex adult whorls. *R. alajuela* (Olsson) (1922, p. 145, pl. 10, fig. 30) from the Gatún formation of Costa Rica is a much smaller species, has a fourth spiral on

later whorls, and only a single small fold on the columella. *R. chipolana* (Dall) (1892, p. 290, pl. 22, fig. 8) from the Chipola formation of Florida is a smaller species with coarser sculpture and only one columellar fold. *R. caloosaensis* (Dall) (1892, p. 291, pl. 14, fig. 3a) from the Pliocene of Florida is also a smaller and a more slender species with coarser spiral sculpture.

Occurrence.—N.V.P. Blue No. 3892, Re 1148, Re 1199.

Distribution.—Manzanilla Miocene, Trinidad.

Family SCALARIIDAE (Epitoniidae)

Genus SCALINA Conrad

Conrad, 1865, Amer. Jour. Conch., vol. 1, p. 27.

Type species (by subsequent designation, Palmer, 1937, Bull. Amer. Paleont., vol. 7, No. 32, p. 102), *Scala staminea* Conrad.

Scalina pseudoleroyi (Maury)

Pl. 65, fig. 6

1925. *Epitonium* (*Acrilla*) *pseudoleroyi* Maury, Bull. Amer. Paleont., vol. 10, No. 42, p. 242.

1928. *Ferminoscala pseudoleroyi* (Maury), Woodring, Carnegie Inst. Wash., Pub. 385, p. 402, pl. 32, figs. 3, 4.

1959. *Scalina pseudoleroyi* (Maury) Woodring, U.S. Geol. Sur., Prof. Paper 306-B, p. 187, pl. 38, figs. 6, 21.

Holotype.—U.S. Nat. Mus., No. 115437.

Remarks.—There is a single shell of nearly five whorls measuring 12.2 mm. in length, which probably belongs to this species. Woodring mentioned irregularly set, slightly varicose axial ribs for both, the material from Bowden and that from the Panamá Canal Zone. Such ribs are not present on this specimen, but apparently instead of them, there are, from time to time, two axials with narrower interspace than the others have which may even join themselves. This feature gives the impression of a strengthening of the axial sculpture. The angulation of the feebly lamellar axials just below the suture is weak. The shell is best comparable with Woodring's (1928) figure 4 on plate 32, its apical angle being about the same. The spiral sculpture is somewhat more accentuated than the axial one which is also indicated by Guppy's figure (1874, pl. 16, fig. 10). Woodring's 1959-figures, however, show a more prominent axial sculpture.

Comparisons.—*S. ferminiana* (Dall) (1908, p. 316, pl. 8, fig. 8) and *S. weigandi* (Böse) (in Böse and Toulou 1910, p. 228, pl. 12,

fig. 8) are both more rapidly tapering than *S. pseudoleroyi*. They have been compared by Woodring (1959, p. 187). A similar species is the Californian *S. whitei* (Keen) (1943, p. 46, pl. 4, figs. 32, 33). Axial and spiral sculptures are about equal in strength. The uppermost portion of the whorl is flattened or even slightly concave. *S. manabia* (Pilsbry and Olsson) (1941, p. 37, pl. 2, fig. 3) and *S. eleutheria* (Pilsbry and Olsson) (1941, p. 38, pl. 2, fig. 7) from the Pliocene of western Ecuador have both the same pattern of sculpture as *S. pseudoleroyi*. The former is larger, has stouter whorls, and tapers more rapidly. The latter has a more prominent spiral sculpture, and there seem to be no irregularities of ornamentation. The Recent *S. retifera* (Dall) (1889, p. 312) with its scalloped axials already represents another modification of sculpture.

Occurrence.—N.V.P. Blue No. 3892.

Distribution.—Bowden formation, Jamaica. Gatún formation, Panamá Canal Zone.

Genus **CIRSOTREMA** Mörch

Mörsch, 1852, Catalogus Conchyliorum . . . Comes de Yoldi, p. 49.

Type species (by monotypy), *Scalaria varicosa* Lamarck.

Cirsotrema undulatum, n.sp.

Pl. 65, figs. 2-5, 7, 8

Shell of medium size. General outline turreted. Protoconch missing. Postnuclear whorls probably between six and eight. Spiral sculpture consists of four low and rounded primary cords with three to five faint secondaries in the interspaces. This spiral sculpture is inconspicuous compared with the prominent axials, which number 18 to 21 per whorl, the number remaining the same on young and adult whorls. Rarely the axials are thickened. Below the suture they are angulated thus forming a shoulder. They are composed of numerous undulating lamellae. Ridge of basal disc prominent. Aperture nearly circular. Outer lip strengthened by the last axial. Inner lip thin. No umbilicus.

Holotype.—Basel Natural History Museum, No. H 13670.

Dimensions of holotype.—Height 25 mm., greatest diameter 12.3 mm.

Remarks.—The material consists of the holotype and two paratypes. One of the paratypes (H 13671) has but 18 axials per whorl, only the last and some scattered ones being angulated at the

shoulder. This gives the impression of a different form with strongly convex whorls. Both forms, however, are united here, since it is believed that the missing angulations at the shoulder are broken off. Further material would show, whether this is correct or not.

Thin sections (H 13669/1-4) across the axials clearly show that they are composed of numerous undulating lamellae. The undulations do not have always the same rhythm ("phase") thus causing some irregularities. The single lamellae consist of cryptocrystalline calcite. The optical orientation of these crystals is indeterminate.

Comparisons. — *S. harbisonae* Sohl¹ (1963, p. 748, pl. 89, figs. 16-19) from the Ripley formation (Upper Cretaceous) of Mississippi, the type species of *Striaticostatum*, differs from *C. undulatum* in having less axials per whorl, a less conspicuous spiral sculpture, and a less steep sutural slope (sutural angle of authors). In addition *C. undulatum* has somewhat higher whorls. According to Sohl's figures, the axials of *S. harbisonae* seem to have the same or a similar structure as those of *C. undulatum*. The Recent *C. pilsbryi* (McGinty) (1940, p. 62, pl. 3, fig. 13) from Florida is a smaller species with more numerous whorls and closer set axials which may touch one another, whereas in *C. undulatum* there is always an interspace about as wide as the axials. *C. undulatum* never shows the prominent occasional varices as present on the Recent *C. dalli* Rehder (1945, p. 128; Clench and Turner, 1950b, p. 227, pl. 98, fig. 1), *C. arcella* Rehder (1945, p. 128; Clench and Turner, 1950b, p. 227, pl. 98, fig. 3), and the fossil forms as *C. (Cirsotremopsis)* cf. *C. arcella* Rehder (See Woodring, 1959, p. 186, pl. 38, figs. 10, 18) from the Gatún formation of the Panamá Canal Zone, *C. tamanense* (Maury) (1925, p. 242, pl. 37, fig. 4) from the Miocene of Trinidad, and *C. collazoense* (Hubbard) (1920, p. 135, pl. 22, figs. 1, 2) from the San Sebastian shale of Puerto Rico.

Occurrence. — N.V.P. Blue No. 3892.

¹ Sohl (1963, p. 747) proposed the genus *Striaticostatum* for a group of Cretaceous species on the Atlantic and Gulf Coastal Plains. *Striaticostatum* is closely related to *Cirsotrema*.

Family **HIPPONICIDAE**Genus **HIPPONIX** Defrance

Defrance, 1819, Journal de Physique, de Chimie, d'Histoire Naturelle et des Arts, vol. 88, p. 217.

Type species (by subsequent designation, Gray, 1847, Zool. Soc. London, Proc., pt. 15, p. 157), *Patella cornucopia* Lamarck.

Hipponix ceras Woodring

Pl. 65, fig. 1

1928. *Hipponix ceras* Woodring, Carnegie Inst. Wash., Pub. 385, p. 374, pl. 29, figs. 10-13.

Shell of small to medium size, moderately high. Apex situated near posterior margin. Nucleus smooth, its coiling not recognizable. Sculpture consists of radial ribs and more or less accentuated concentric lamellae causing a somewhat reticulated pattern. Aperture oval. Muscle impression immediately behind margin; wide at its anterior ends.

Holotype.—U.S. Nat. Mus., No. 369519.

Remarks.—This species is represented by four shells, the smallest of which is still larger than Woodring's largest specimen. Despite this discrepancy of size they are assigned to *H. ceras*, because the other characteristics are identical with the material from Bowden. Height and intensity of sculpture are somewhat variable.

Comparisons.—*H. tampensis* Mansfield (1937a, p. 171) (= *H. pygmaeus* Dall, 1915, not of Lea) from the Tampa limestone of Florida is smaller, thicker-shelled, and less strongly sculptured. The figures of *H. portoricoensis* Hubbard (1920, p. 132, pl. 21, figs. 5, 6) are not clear enough to allow a comparison. It is said to have bifurcating radial ribs which is rarely the case in this material. *H. ornatus* Dickerson (1917, p. 181, pl. 31, figs. 12a, 12b), a Pacific Coast species, is astonishingly similar. However, its apex is slightly overhanging the posterior margin.

Occurrence.—N.V.P. Blue No. 3892.

Distribution.—Bowden formation, Jamaica.

Family **CALYPTRAEIDAE**Genus **CALYPTRAEA** Lamarck

Lamarck, 1799, Mém. Soc. Hist. Nat. Paris, p. 78.

Type species (by monotypy), *Patella chinensis* Linné.

Subgenus **TROCHITA** Schumacher

Schumacher, 1817, Essai d'un nouveau système des habitations des vers testacés, pp. 57, 184.

Type species (by subsequent designation, Rehder, 1943, Biol. Soc. Washington, Proc., vol. 56, p. 41): *Trochita spiralis* Schumacher (= *Trochus radians* Lamarck).

Calyptrea (Trochita) cf. radians (Lamarck) Pl. 66, figs. 1, 2

1816. *Trochus radians* Lamarck, Encycl. Méthodique, Vers, vol. 3, pl. 445, fig. 3, a, b! Liste, p. 10.

Remarks.—A single fragment, which is tentatively attributed to *C. (T.) radians*, is represented in the collection. This species has been described, figured, and discussed by Woodring (1957, p. 81, pl. 19, figs. 11-14). The radial sculpture of the specimens figured by Woodring is coarser. Their ribs are broader and rounded, whereas this fragment has somewhat flat-sided and relatively high ribs with wider interspaces. The figure given by Grant and Gale (1931, pl. 31, fig. 11) shows a shell with a radial sculpture more similar to that of the present specimen. The platform joins the main shell at some distance from the basal margin as shown by Reeve's figure (1859, Conch. Icon., *Trochita*, pl. 1, fig. 3b).

Occurrence.—N.V.P. Blue No. 3892.

Genus **CRUCIBULUM** Schumacher

Schumacher, 1817, Essai d'un nouveau système des habitations des vers testacés, pp. 56, 182.

Type species (by subsequent designation, Burch, 1946, Conchological Club Southern California, Proc., No. 56, p. 19), *Crucibulum planum* Schumacher.

Subgenus **DISPOTAEA** Say

Say, 1824, Acad. Nat. Sci. Philadelphia, Jour., 1st ser., vol. 4, p. 131.

Type species (by subsequent designation, Olsson and Harbison, 1953, Acad. Nat. Sci. Philadelphia, Mon. No. 8, p. 276), *Calyptrea costata* Say.

Crucibulum (Dispotaea) waltonense Gardner Pl. 66, figs. 3, 4

1947. *Crucibulum (Dispotaea) waltonense* Gardner, U.S. Geol. Sur., Prof. Paper 142-H, p. 568, pl. 56, figs. 16, 17.

? 1962. *Crucibulum (Dispotaea) marensense* Weisbord, Bull. Amer. Paleont., vol. 42, No. 193, p. 218, pl. 20, figs. 10, 11.

Shell of medium size. Protoconch consists of about $1\frac{3}{4}$ volutions. Radial sculpture beginning after an area with incremental lines only. Radial ribs rounded, close set, crossed by fine growth

lines. Attachment area of elongate inner cup relatively small. Margin of shell crenulated.

Holotype. — U.S. Nat. Mus., No. 371873.

Variability. — The following remarks are based on 11 shells. The strength of the crenulation of the inner margin varies with the strength of the radial ribs. These may be straight, somewhat sinuous, or dichotomous. Sometimes additional ribs are inserted between the others toward the periphery. In a few cases two ribs, especially in late stages, may fuse and they may continue as a broad rib. The attachment area of the cup has a somewhat variable extension. In a few shells it is small and thus approaches *Crucibulum s.str.*

Comparisons. — *C. mareense* Weisbord is tentatively put in the synonymy of *C. waltonense*. On the base of the original description and figures it is difficult to separate them. The type of sculpture is the same, slightly coarser in *C. waltonense*, but both falling within the variability of this material. Dimensions and shape of cup are comparable. The radial ribs of *C. chipolanum* Dall (1892, p. 349) are closer set. Other differences have been pointed out by Gardner (1947, p. 568). The illustration of *C. collazum* Hubbard (1920, p. 134, pl. 21, fig. 10) from the San Sebastian shale of Puerto Rico is not clear enough to allow a comparison. The Recent *C. personatum* Keen (1958, p. 247, pl. 30, figs. 6-8) from Panamá (Pacific Coast) has a finer radial sculpture with primaries and secondaries. Its apex is more centrally placed and not recurved.

Occurrence. — N.V.P. Blue No. 3892.

Distribution. — Shoal River formation (middle Miocene), Florida. Mare formation (Pliocene), Venezuela ?

Crucibulum (Disputaea) ecuadorensis Olsson

Pl. 66, figs. 5, 6

1932. *Crucibulum* (*Crucibulum*) *ecuadorensis* Olsson, Bull. Amer. Paleont., vol. 19, No. 68, p. 212, pl. 24, fig. 11.

1951. *Crucibulum* (*Crucibulum*) *ecuadorensis* Olsson, Marks, Bull. Amer. Paleont., vol. 33, No. 139, p. 94.

Addenda to original description. — Protoconch consisting of $1\frac{3}{4}$ volutions. Protoconch followed by a more or less small area sculptured by incremental lines only without radials. Radial ribs coarse with corresponding crenulation of the inner margin of the shell. Attachment area of cup relatively large.

Holotype. — Pal. Res. Inst., Ithaca, New York, No. 2348.

Variability.—The height of the shell is variable. The material shows a tendency towards high shells. For variability of radial sculpture see under *C. waltonense*.

Remarks.—The interior of the holotype is not known. Olsson gave a single figure of the holotype. A view of the profile is missing. Therefore, my determination must remain somewhat questionable.

Comparisons.—*C. multilineatum* (Conrad) (1841, p. 346, pl. 2, fig. 8; Martin 1904, pl. 58, figs. 12a, b; Gardner 1947, p. 569) is similar in sculpture, size, and shape, and attachment area of cup but differs mainly in having spinose radial ribs. The Recent *C. striatum* (Say) (1826, p. 216), which according to Abbott (1954, p. 170) ranges from Nova Scotia to South Carolina (and Florida ?), has finer radial ribs and a more regularly reniform cup. Olsson compared his form with *C. imbricatum* (G. B. Sowerby II), but this species has even coarser ribs and a free cup thus belonging to *Crucibulum s.str.*

Occurrence.—N.V.P. Blue No. 3892.

Distribution.—Progreso formation (middle Miocene), Ecuador.

Genus **CREPIDULA** Lamarck

Lamarck, 1799, Mém. Soc. Hist. Nat. Paris, p. 78.

Type species (by monotypy), *Patella fornicata* Linné.

Crepidula cantaurana F. Hodson

Pl. 66, figs. 10; 11

1931. *Crepidula cantaurana* F. Hodson, in Hodson and Hodson, Bull. Amer. Paleont., vol. 16, No. 60, p. 8, pl. 6, figs. 3-5.

Shell large and flat. Apex near the margin. Protoconch coiled, consists of about $1\frac{1}{4}$ volutions. Sculpture consists of coarse, partly irregular radial ribs, rarely dichotomous towards the periphery. Radials crossed by growth lines, without spines. Inner margin sometimes undulating corresponding to the external radial ribbing. Deck covering more than half of the inner surface of the shell.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 24135.

Remarks.—There is a single fairly complete specimen and several fragments. The external surfaces of most of them are encrusted by organisms. The holotype is circular in outline, whereas

these shells are oval. Hodson's material comes from Cantaure.

Comparisons.—Hodson compared his species with *C. dilatata* Lamarck (1822, p. 25). This species, however, is different: the outer surface is nearly smooth, the shell much more concave, the deck smaller and concave. The only species comparable with *C. cantaurana* is *C. costata* Morton (1827, p. 115, pl. 7, figs. 2, 3), originally described from the Tertiary of Maryland. Gardner (1947, p. 563) treated it as a subspecies of *C. aculeata* Gmelin. It mainly differs from *C. cantaurana* by its smaller deck and the finer radial riblets.

Occurrence.—N.V.P. Blue No. 3892.

Distribution.—Known from holotype locality only.

Subgenus **CREPIPATELLA** Lesson

Lesson, 1830, Zoologie, in Duperry, Voyage autour du monde, exécuté par ordre du Roi, sur la corvette de S. M. La Coquille, pendant les années 1822-25.

Type species, *Crepidula dilatata* Lamarck (see Wenz, 1938, Handbuch der Paläozoologie, Bd. 6, p. 903).

Crepidula ? (Crepidatella ?) insculpta, n.sp.

Pl. 66, figs. 7-9

Shell of medium size, moderately high. Apex excentric. Protoconch consists of nearly one volution. Radial sculpture absent. Concentric growth lines more or less pronounced. Shortest slope between apex and margin of shell slightly concave, longest slope convex. Attachment area of cup large.

Holotype.—Basel Natural History Museum, No. 13680.

Dimensions of holotype.—Height 7.0 mm., greatest diameter 21.6 mm.

Remarks.—It is difficult to assign this species to a genus with certainty. The lack of radial ribs, the excentric apex, and the features of the inner cup shown by Keen (1963, p. 12) suggest *Crepidatella*, which is treated by Keen as a genus, by Wenz (1938, Handbuch der Paläozoologie, Bd. 6, p. 903) and Davies (1935, Tertiary Faunas, vol. 1, p. 244) as a subgenus of *Crepidula*. The type of *Crepidatella* is *C. dilatata* Lamarck (1822, p. 25), three specimens of which from the west coast of South America are at hand. *C. dilatata* is a large and high species with a heavy shell. Its apex is situated near the margin of the shell. The deck is relatively larger than on the present specimens, where it approaches the cup

of a *Dispotaca* but with an even larger attachment area. Thus the form studied seems to be intermediate between *Crepidatella* and *Dispotaca*.

Comparisons.—The form described as *Calyptrea saxosa* by Olsson (1928, p. 63, pl. 13, figs. 11, 12) from the Saman formation (upper Eocene) of Perú is somewhat similar at first glance. It is said to have a small and erect spire which is not the case in the material at hand. *C. saxosa* is also higher. The figure given by Pilsbry and Olsson (1941, pl. 7, fig. 2) for *Crucibulum inerme* Nelson (1870, p. 188) shows a few radial ribs at the posterior end; those given by Olsson (1932, pl. 24, figs. 4, 7) none. The apex is placed nearly in the center. No view of the interior of this species has been found. The cup is said to be typical for *Dispotaca*. *Crucibulum (Dispotaca) venezuelanum* Weisbord (1962, p. 219, pl. 20, figs. 12-14) is a minute species from the lower Mare formation of Venezuela with a wide attachment area of the cup. The figure seems to represent a young individual. Undulations at the margin seem to indicate later radial riblets. *Crepidula juliella* Weisbord (1962, p. 213, pl. 19, figs. 14, 15), also from the Mare formation, is proportionately higher. The holotype is an immature shell and thus not favourable for comparison. The features of the cup, however, are similar.

Occurrence.—N.V.P. Blue No. 3892.

Family CYPRAEIDAE

Genus CYPRAEA Linné

Linné, 1758, Systema Naturae, ed. 10, p. 718.

Type species (by subsequent designation, Montfort, 1810, Conchyliologie systématique, vol. 2, p. 631), *Cypraea tigris* Linné.

Cypraea aff. *isabella* Linné

Pl. 67, figs. 7, 8

Remarks.—The single well-preserved specimen at hand has been indicated by Schilder (1939, p. 26) (Basel Natural History Museum, No. H 11286) under the name of *Luria (Basilitrona) patrespatriae* (Maury). In 1922, Pilsbry (p. 364) put *C. patrespatriae* in the synonymy of *C. isabella*. Woodring (1928, p. 317) considered it as a subspecies of *C. isabella*. Ingram treated it as a synonym in several papers.

The specimen, however, is not identical with *C. isabella*. Its lateral margins are less flattened. The border line of the callus is well accentuated on the right part of the shell. The fossula and the columellar groove are strongly toothed in contrast to *C. isabella*.

On the other hand the description of *C. fossula* Ingram (1947, p. 4, pl. 1, fig. 3) from Cantaure, Paraguana, agrees well with the present shell except that it is much smaller than *C. fossula*. It measures 24.2 mm. in length, 16.5 mm. in width, and 13.2 mm. in height. Moreover its base is less flattened. Unfortunately I am not in possession of material for comparison. It is possible that the shell at hand represents an immature stage of *C. fossula*.

Occurrence. — N.V.P. Blue No. 3892.

Genus **MARGINOCYPRAEA** Ingram

Ingram, 1947, Bull. Amer. Paleont., vol. 31, No. 121, p. 3.

Type species (by original designation), *Sphaerocypraea wegeneri* Schilder (= *Marginocypraea paraguana* Ingram).

Marginocypraea wegeneri (Schilder)

Pl. 67, figs. 1-4

1939. *Sphaerocypraea wegeneri* Schilder, Abh. Schweiz. Pal. Ges., Bd. 62, p. 12, figs. 6-8.

1947. *Cypraea wegeneri* (Schilder), Ingram, Bull. Amer. Paleont., vol. 31, No. 120, p. 62.

1947. *Marginocypraea paraguana* Ingram, Bull. Amer. Paleont., vol. 31, No. 121, p. 3, pl. 1, figs. 1, 2.

The following is a translation of the original description: Shell oblong-oval, moderately inflated. Right margins and ends with thick callus. Band of callus broad extending over the back, where it is sharply bordered. Lips of base regularly convex. Outer lip not declivous anteriorly. Aperture curved posteriorly. Outer teeth sharp at margin of aperture, thickening outwards, moderately extended, or reaching to the outer margin anteriorly, but only to the middle of the outer lip in the central part of the shell and posteriorly. Terminal fold at anterior end of inner lip coarsely two-folded (nearly three-folded). Along the arched and well accentuated border of the aperture the inner teeth are at least anteriorly short and sharp but not thick. More posteriorly they are less distinct and sitting on a keel. Posteriorly they are more conspicuously folded again, but not strengthened. Fossula broad, obliquely

inclined, flat, transversely ribbed, without groove behind the anterior edge. Columella with a keel in prolongation of the inner margin of the fossula. Thus a broad and flat columellar groove is formed. The inner ridge carries coarse teeth-knots which are connected anteriorly with the inner teeth. They may disappear centrally, but are always strengthened posteriorly, situated on an elevated ridge (this feature of the inner row of knots resembles in its posterior part the accentuated posterior inner teeth of other genera, e.g. *Transovula*). Back side of shell smooth, with growth lines, but without fine, wavy spiral ribs present in *Eocypraea*. Only fossula and columella are minutely striated in the direction of the main shell axis. Cast oval, outer lip somewhat flattened, inner lip pointed in front and slightly twisted backwards and dextral. Behind it, at the aperture, somewhat impressed. Hole of spire deep, the back portion projecting over it much more than the posterior end of the inner lip. It is clearly widened in an up-dextral direction but much less than in *C. obovata* Schafhäütl. The anterior teeth and the strengthened posterior inner knots of the columella are mostly well impressed on the cast.

Holotype.—Basel Natural History Museum, No. H 11240.

Remarks.—All the Cypraeacea from the Caribbean region in the Basel Natural History Museum have been described by Schilder (1939). Among this material there are four specimens from N.V.P. Blue No. 3892 described as *Sphaerocypraea wegeneri*. Its holotype is refigured here (Pl. 67, fig. 1). Additional material from Paraguaná, which has been received recently, contains 15 specimens apparently belonging to this species. Most of them are casts, the largest (H 13682) measures 81 mm. in length and 60 mm. in width. On one well-preserved specimen (H 13681) an additional morphological feature may be noticed: three of the anterior outer teeth are dichotomous in their outer half.

In 1947 Ingram described *Marginocypraea paraguana* as the type species of his new genus *Marginocypraea*. This description agrees well with this material. Ingram stated that there is a great variation in size which is shown also by these specimens. The type locality of *M. paraguana* lies 200 m. north of 3892. Because the strata are nearly horizontal in this region, Ingram's specimens agree with these also stratigraphically. There is no doubt about the

identity of Ingram's species and *S. wegneri*. Therefore the name *paraguana* must be dropped.

Comparisons.—Woodring compares his *Eocypraea* (*Apiocypraea* ?) *keenae* (1959, p. 196, pl. 32, figs. 8, 10) from the middle part of the Gatún formation (middle Miocene) of the Panamá Canal Zone with *M. paraguana*.

Occurrence.—N.V.P. Blue No. 3892, Re 1148, Re 1152, Re 1153, Re 1154, Re 1155, Re 1199.

Distribution.—Except from Paraguaná this species has been recorded from the St. Croix member of the Brasso formation of Trinidad (Adivinanza Estate) which is assumed to belong to the *Globigerinatella insueta* Zone.

Family NATICIDAE

Genus NATICA Scopoli

Scopoli, 1777, *Introductio ad historiam naturalem*, p. 392.

Type species (by subsequent designation, Harris, 1897, *Catalogue of Tertiary Mollusca in the British Museum*, pt. 1, *Australasia*, p. 255), *Nerita vitellus* Linné.

Subgenus NATICARIUS Duméril

Duméril, 1806, *Zoologie analytique*, p. 164.

Type species (by monotypy), *Nerita canrena* Linné (see Woodring 1957, p. 85).

Natica (Naticarius) canrena antinacca Cossmann Pl. 67, figs. 5, 6, 9

1924. *Natica antinacca* Cossmann, *Essais de paléoconchologie comparée*, pt. 13, p. 110, pl. 1, figs. 11-14.

1928. *Natica (Naticarius) canrena antinacca* Cossmann, Woodring, *Carn. Inst. Wash. Pub.* 385, p. 380, pl. 30, figs. 6-8.

1951. *Natica canrena antinacca* Cossmann, Masson and Alencaster, *Bol. Assoc. Mex. Geol. Petrol.*, vol. 3, Nos. 5-6, p. 209, figs. 19-22.

1960. *Natica (Naticarius) canrena antinacca* Cossmann, Perrilliat Montoya, *Paleontologia Mexicana*, No. 8, p. 19, pl. 3, figs. 6, 7.

Shell of medium size. Nuclear whorls nearly two and a half. Adult individuals have about five whorls sculptured by opisthocline short wrinkles. Funicle not thick. Umbilical groove wide. Parietal callus prominent.

Type.—The type is the shell figured by Cossmann (Woodring, 1928, p. 381). Depository, Paris ? Pflug (1961, p. 35) could not find Cossmann's type in the Cossmann collection.

Variability.—The wrinkles below the suture may be obscure and look like growth lines. The strength of the funicle is not constant. The umbilical groove usually is wide but may be narrow.

Remarks.—The numerous specimens differ in the following points from material from Bowden at hand: the shells have higher spires throughout, *i.e.* their whorls are less covered by the succeeding ones than it is the case in Bowden shells. The angle between the body whorl and the penultimate whorl at the suture above the aperture has about 90° . In Bowden shells this angle is much larger. But extreme varieties approach the form from Paraguaná. The collection does not contain any opercula.

Comparisons.—The Recent *N. canrena*, many specimens of which are at hand, is larger. The largest Recent shells are twice as high as the largest specimens from Paraguaná. The spire and especially the nuclear whorls are lower in *N. canrena s.str.* and, as pointed out by others, the initial whorl is larger than in *N. antinacca*. The form described by Pflug (1961, p. 34, pl. 6, figs. 8, 9) as *N. canrena canrena* from the Dominican Republic seems to be intermediate between *N. canrena s.str.* and *N. antinacca*. Specimens from the Springvale formation of Trinidad determined as *N. canrena s.str.* are nearer to the Recent form than to the fossil, *i.e.* they are larger and have a lower spire. However, their initial whorl is not yet as large as in Recent specimens, but larger than in *N. antinacca*. *N. precanrena* F. Hodson (*in* Hodson, Hodson, and Harris, 1927, p. 68, pl. 36, figs. 2, 6, 9) is a much smaller species with more sloping shoulders. *N. stenopa* Woodring (1957, p. 85, pl. 20, figs. 4-6) from the Gatún formation of the Panamá Canal Zone has been compared to *N. canrena s.str.* by Woodring. From *N. antinacca* it differs mainly by its less inflated whorls. The average sculpture seems to consist of closer spaced wrinkles than in *N. antinacca*. *N. precursor* Gardner (1947, p. 545, pl. 59, figs. 1, 2, 6) from the Chipola formation of Florida is smaller than medium-sized specimens of this material but otherwise seems to be similar.

Occurrence.—N.V.P. Blue No. 3892, Re 1148, Re 1155.

Distribution.—Bowden formation, Jamaica. Miocene of the Isthmus of Tehuantepec, México. Miocene of the Veracruz region,

México. Many of the citations given by Woodring (1928, p. 381) probably refer to *N. antinacca*.

Genus **POLINICES** Montfort

Montfort, 1810, Conchyliologie systématique, vol. 2, p. 223.

Type species (by original designation), *Polinices albus* Montfort.

Polinices nelsoni Olsson

Pl. 68, figs. 1, 2

1870. *Polinices subangulata* Nelson, *partim*, Trans. Conn. Acad. Arts and Sci., vol. 2, pt. 1, pl. 6, fig. 4 (not figs. 12, 13).

1932. *Polinices (Polinices) nelsoni* Olsson, Bull. Amer. Paleont., vol. 19, No. 68, p. 208, pl. 24, figs. 8, 10.

Addenda to original description.—Nuclear whorls about $2\frac{1}{4}$. Initial whorl small. Except the transverse groove near the upper end of the umbilicus, there is another groove at about right angle to the former situated on the columella. It may extend up to the posterior end of the aperture.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 2347.

Remarks.—There are about 20 specimens of this species. Compared with the original figure the shells have somewhat higher spires. In large specimens (height 19.2 mm.) (H 13694) the upper part of the body whorl is concave. According to Olsson's description there is a small funicular rib. This is not the case in any of these shells.

Comparisons.—This species differs mainly from *P. brunneus subclausus* (G. B. Sowerby I) (1850, p. 51) from the Cercado and Gurabo formations of the Dominican Republic by its more slender form and the inconspicuous umbilical callus. Specimens from Bowden in the present collection reach a considerably larger size. *P. subclausus lavelanus* F. Hodson (*in* Hodson, Hodson, and Harris, 1927, p. 69, pl. 36, fig. 8; pl. 37, figs. 12, 14) has a notch in the callus near the upper end of the umbilicus; it is larger and less slender. The specimen figured by Woodring (1957, pl. 21, fig. 14) as *P. stanislasmunieri* from the lower Gatún formation of the Panamá Canal Zone has a similar outline but differs in umbilical details. *P. coronis* (Hanna and Israelsky) (1925, p. 46, pl. 8, fig. 4) from the Zorritos formation of Perú seems to be somewhat related to this material. *P. coronis* is larger, however, and has

a heavier parietal and umbilical callus. The transverse groove near the upper end of the umbilicus is absent. Numerous specimens of the Recent *P. albus* (= *brunneus*) from Barbados are at hand. They differ from *P. nelsoni* by their lower spire, the more inflated body whorl, and in umbilical details.

Occurrence.—N.V.P. Blue No. 3892, Re 1199 (?).

Distribution.—Tumbes formation (upper Miocene), Perú.

Genus **NEVERITA** Risso

Risso, 1826, Histoire naturelle des principales productions de l'Europe méridionale et particulièrement de celles des environs de Nice et des Alpes maritimes, vol. 4, p. 149.

Type species (by monotypy), *Neverita josephinia* Risso.

Neverita paraguanensis F. Hodson

Pl. 67, figs. 10-12

1927. *Polinices* (*Neverita*) *paraguanensis* F. Hodson, in Hodson, Hodson, and Harris, Bull. Amer. Paleont., vol. 13, No. 49, p. 71, pl. 38, figs. 2-4.

Shell of medium to large size. Nuclear whorls about $2\frac{1}{4}$. Spire low. Whorls slightly convex. Suture not conspicuous. Sculpture consists of faint, close-set, and prosocline growth lines which become more accentuated towards the umbilicus. Base of aperture thicker than outer lip. Callus of inner lip thick. Parietal fold moderately developed. Funicle thick, mostly covering the whole umbilicus.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 22873.

Variability.—The size and shape of the funicle is variable. It may be flattened and cover the umbilicus entirely. In this case its periphery thins out and is appressed to the body whorl. Or it may be higher, more ball-shaped, leaving a deep furrow along the margin of the umbilicus.

Remarks.—The holotype of this species has a diameter of 24.5 mm. The largest of the numerous specimens (H 13689) measures 47.3 mm. in diameter and 33.3 mm. in height. In the original description Hodson mentioned faint, close-set spirals on the whorls. The material does not show these spirals or in obscure traces only. Hodson separated specimens, the funicles of which do not completely cover the umbilicus, as the subspecies *N. quirosana* from *N. paraguanensis* s.str. The above mentioned variability of the shape of the funicle indicates that it cannot be used as a diagnostic feature. *N. quirosana*, however, is mainly separated from *N. paraguanensis* by its smaller apical angle, i.e. its higher spire, and the

much steeper flanks of the body whorl. *N. quirosana* has also been reported from the Mancora and Chira formations of Perú by Olsson (1931, p. 69).

The holotype of Hodson's subspecies *N. buchivacoana* is a poor specimen. It is closer to *N. quirosana* than to *N. paraguayensis*.

In contrast to *Glossaulax* the umbilical callus of the present material is not divided into two parts by a groove.

Comparisons. — *N. samanensis* Olsson (1928, p. 59, pl. 13, figs. 4, 5) from the Saman formation (upper Eocene) of Perú has a higher spire, i.e. a considerably smaller apical angle. *Polynices porcana* Spieker (1922, p. 88, pl. 4, fig. 9) from the lower Zorritos formation of Perú has a heavy, undivided umbilical callus according to the original figure. A satisfactory comparison is not possible because of the insufficient figure. Spieker compared his species with the type species of *Neverita*, *N. josephinia* Risso. *N. josephinia* is similar to the Venezuelan fossil. Recent specimens from the Mediterranean Sea and Pliocene fossils from northern Italy are at hand. Sacco (1891, p. 84) reported this species from the Tortonian of Stazzano and Sant'Agata, two localities within the vicinity of the type Tortonian. The spire of *N. josephinia* is slightly lower. Generally the funicle does not completely fill the umbilicus.

Occurrence. — N.V.P. Blue No. 3892, Re 1148, Re 1154, Re 1199.

Distribution. — Miocene, Venezuela.

Genus **SINUM** Röding

Röding, 1798, Museum Boltenianum, pt. 2, p. 14.

Type species (by subsequent designation, Dall, 1915, U.S. Nat. Mus., Bull. 90, p. 109), *Helix haliotideae* Linné.

Sinum gabbi (Brown and Pilsbry)

Pl. 68, figs. 3, 4

1913. *Sigartus (Eunaticina) gabbi* Brown and Pilsbry, Acad. Nat. Sci. Philadelphia, Proc., vol. 64, p. 509, pl. 22, fig. 13.

1957. *Sinum gabbi* (Brown and Pilsbry), Woodring, U.S. Geol. Sur., Prof. Paper 306-A, p. 94, pl. 21, figs. 3, 6.

Shell of medium size. Protoconch consisting of $2\frac{1}{4}$ to $2\frac{3}{4}$ volutions. Adult shells have about $4\frac{1}{2}$ whorls. Spiral sculpture consisting of not quite regularly spaced ribs with one or two intervening threads. Generally these spirals are crinkled by growth lines but sometimes even set off.

Type.—Acad. Nat. Sci. Philadelphia, No. 3845.

Remarks.—The type is, as stated by Woodring, a young individual. The measurements of the largest specimen in this collection are: height 17.5 mm., diameter 18.4 mm. (H 13695). The apertures of these shells are somewhat less elongate than that figured by Woodring.

Comparisons.—Woodring placed tentatively *S. quirosanum* F. Hodson (*in* Hodson, Hodson, and Harris, 1927, p. 67, pl. 36, figs. 10, 12) in the synonymy of *S. gabbi*. This species, however, is considerably smaller, has $4\frac{1}{2}$ whorls like the present adult shells, which are nearly twice as high as *S. quirosanum*. Moreover the aperture of Hodson's type is nearly circular, and not oval like in the material from Paraguaná. *S. carolanum* Spieker (1922, p. 89, pl. 4, fig. 10) from the Zorritos formation of Perú is a more flattened species with more nuclear whorls. *S. naticoidale* Vokes (1938, p. 27, figs. 25, 26) from the Springvale formation of Trinidad is a larger species. A specimen from Springvale measures 32.5 mm. in height. Its body whorl is more convex. A young individual from the Punta Gavi-lán formation of Venezuela is more elongate, relatively higher, and has coarser primary spirals. The Recent *S. concavum* (Lamarck) is similar in general outline, but much larger, and has a somewhat more elongate aperture.

Occurrence.—N.V.P. Blue No. 3892.

Distribution.—Gatún formation, Panamá Canal Zone.

***Sinum dodoneum* Gardner**

Pl. 68, figs. 5, 6

1947. *Sinum dodoneum* Gardner, U.S. Geol. Sur., Prof. Paper 142-H, p. 554, pl. 59, figs. 37, 39.

Shell of medium size, depressed, with $3\frac{3}{4}$ whorls. Nuclear whorls slightly more than two. Spirals broad, crinkled by growth lines, their interspaces having the same width as the spirals on the upper part of the body whorl. Towards the periphery the spirals are narrower and closer set. Inner lip somewhat everted. Base small, sculptured by nearly disappearing spirals.

Holotype.—U.S. Nat. Mus., No. 136075.

Remarks.—There is a single, somewhat damaged specimen, which I refer to this species. Gardner stated that there are three nuclear whorls, but her figure showed two only. Faint secondary

spirals are not present on this shell.

Comparisons.—Closely allied to this species is the Recent *S. haliotideum* (Linné), of which there is a single shell for comparison. It is much larger, and has $1\frac{1}{2}$ to $1\frac{3}{4}$ nuclear whorls, which are not slightly elevated over the rest of the spire as in the fossil form. Its degree of depression is similar to that of *S. dodoneum*. *S. gatumense* (Toula) (1909, p. 697, pl. 28, fig. 3) is smaller and much more depressed. *S. euryhedra* Woodring (1957, p. 93, pl. 21, figs. 4, 7, 10), known from the Gatún formation of the Panamá Canal Zone and Bowden, Jamaica, has $1\frac{1}{2}$ nuclear whorls only, a larger base, and a more conspicuous umbilical groove. *S. excentricum* (Guppy) (1876, p. 519, pl. 29, fig. 11) is smaller, has a less elongate aperture according to Woodring's figures (1928, pl. 31, figs. 5, 6), but not in the original figure, and has the umbilicus not covered. The Recent *S. sanctijohannis* (Pilsbry and Lowe) (1932, p. 84, pl. 9, fig. 7) differs mainly by its greater height compared to its diameter.

Occurrence.—N.V.P. Blue No. 3892.

Distribution.—Oak Grove sand, Florida.

Family CASSIDIDAE

Genus SCONSIA Gray

Gray, 1847, Zool. Soc. London, Proc., pt. 15, p. 137.

Type species (by original designation), *Cassidaria striata* Lamarck.

Sconsia laevigata laevigata (G. B. Sowerby I)

Pl. 68, figs. 7, 8

1850. *Cassidaria laevigata* G. B. Sowerby I, Quart. Jour. Geol. Soc. London, vol. 6, p. 47, pl. 10, fig. 2.

1961. *Sconsia* (*Sconsia*) *laevigata laevigata* (G. B. Sowerby I), Pflug, Acta Humboldtiana, ser. geol. et pal., Nr. 1, p. 36, pl. 7, figs. 1-8. For further citations see this publication.

Lectotype.—British Museum (Natural History), No. G 83945.

Remarks.—There is a single but large shell of this species (height 52 mm., greatest diameter 33.5 mm.). Its varices are inconspicuous, the last one being damaged by weathering.

The discussion on the distinction between *S. laevigata s.str.*, *S. laevigata sublaevigata*, and *S. laevigata gabbi* is confusing and partly contradictory. Several authors agree in stating that *S. laevigata s.str.* is distinguished from *S. sublaevigata* by having a more

inflated and somewhat shouldered body whorl (Olsson, 1922, p. 136, Woodring, 1928, p. 310, Rutsch, 1934, p. 54, Woodring, 1959, p. 201, Pflug, 1961, p. 36). The lectotype of *S. laevigata s.str.* selected by Pflug is an immature shell and does not have a shouldered body whorl. Its outer lip regularly slopes down to form an oval aperture. The figured specimen of the Weyl collection, has a more bulging upper part of the body whorl, like the specimen figured by Maury (1917, pl. 19, fig. 2) and the shell from Paraguaná. The uppermost part of the outer lip lies nearly perpendicularly to the main shell axis. On the other hand the original figure of *S. laevigata sublaevigata* (this species being said to have a less inflated body whorl without shoulder) shows a specimen with an outer lip starting posteriorly at a large angle. Guppy distinguished his *S. sublaevigata* from *S. laevigata s.str.* by its larger size and its shorter spire. The shell from Paraguaná is large, has an inflated body whorl, but a high spire. Specimens from Bowden at hand have a more prominent spiral sculpture than the present specimen, and also are distinguishable in the same way from the topotypes of *S. laevigata s.str.* Increasing inflation of the body whorl seems to be connected with the diminishing of the intensity of the spiral sculpture.

The position of *S. laevigata gabbi* Olsson (1922, p. 136, pl. 12, fig. 3) from the Gatún formation of the Panamá Canal Zone is not clear. There are two shells of this species from Water Cay, Panamá, at hand. The larger one has a moderately inflated body whorl with weak spiral sculpture, the smaller one is less inflated, and has a prominent spiral sculpture. Only large series of topotypes could reveal, if reliable differences are present to separate this form satisfactorily from the above mentioned ones.

Comparisons. — *S. paralaevigata* Gardner (1947, p. 537, pl. 54, fig. 11) from the Chipola formation of Florida, despite its inflated body whorl, has a prominent spiral sculpture. Because I do not have topotypes of this species, nothing more can be said. Other comparable forms are discussed by Woodring (1928, p. 309; 1959, p. 201).

Occurrence. — N.V.P. Blue No. 3892.

Distribution. — Gurabo formation, Dominican Republic. See also Woodring (1959, p. 202).

Family **CYMATIIDAE**Genus **DISTORSIO** Röding

Röding, 1798, Museum Boltenianum, p. 133.

Type species (by subsequent designation, Gray, 1847, Zool. Soc. London, Proc., pt. 15, p. 133), *Murex anus* Linné.

For a short discussion of the type designation of *Distorsio* compare Clench and Turner (1957, p. 235). Wenz (1941, Handbuch der Paläozoologie, Bd. 6, p. 1065) also cited Pilsbry (1922) as type designator.

Subgenus **RHYSEMA** Clench and Turner

Clench and Turner, 1957, Johnsonia, vol. 3, No. 36, p. 236.

Type species (by original designation), *Triton clathratum* Lamarck.

Distorsio (Rhysema) decussata gatunensis Toula P. 68, figs. 9-11

1909. *Distorsio (Distortrix, Persona) gatunensis* Toula, Jahrb. K.K. geol. Reichsanstalt, Bd. 58, p. 700, pl. 25, fig. 10.

1911. *Distorsio gatunensis* Toula, Brown and Pilsbry, Acad. Nat. Sci. Philadelphia, Proc., vol. 63, p. 356, pl. 26, fig. 8.

Not 1928. *Distorsio (Distorsio) clathratus gatunensis* Toula, Woodring, Carn. Inst. Wash., Pub. 385, p. 300, pl. 19, figs. 2, 3.

1930. *Distorsio decussatus gatunensis* Toula, Rutsch, Ecl. Geol. Helv., vol. 23, pl. 17, fig. 6 (holotype).

? 1930. *Distorsio decussatus* cf. *gatunensis* Toula, Rutsch, *idem*, pl. 17, fig. 7.

1953. *Distorsio decussatus gatunensis* Toula, Emerson and Puffer, Proc. Biol. Soc. Wash., vol. 66, p. 100.

1959. *Distorsio (Rhysema) decussata gatunensis* Toula, Woodring, U.S. Geol. Surv., Prof. Paper 306-B, p. 205, pl. 34, figs. 7, 10; pl. 36, fig. 5.

Not 1960. *Distorsio (Distorsio) clathratus gatunensis* Toula, Barrios, Bol. Geol., vol. 6, Nos. 1-3, Informe No. 1082, p. 276, pl. 9, fig. 3.

Type.—Technische Hochschule, Vienna.

Remarks.—The material consists of five partly incomplete specimens only. This number does not allow one to note local morphological changes with certainty, when considering the fact that diagnostic characteristics as protoconch, outer lip, and parietal region are represented merely once or twice.

This species has been redescribed thoroughly by Woodring (1959). Together with his discussion of this form and the comparisons with related species, Rutsch's discussion on this group, his refigured holotype, and the summarizing remarks of Pflug (1961, p. 42), it seems undesirable to give another redescription here. A nearly complete protoconch is figured on Plate 68, figure

10 to support another record from the Miocene of Falcón, thought to be questionable by Woodring (1959, p. 206).

Rutsch (1930, p. 609) considered *D. constricta* Broderip as a synonym of *D. decussata* Valenciennes, but Pilsbry and Olsson (1941, p. 40, pl. 5, figs. 9, 12) have shown that they represent two distinct species of the Panamic Province.

The comparisons with other American fossil and Recent species of this genus have been made by the above cited authors. Even the similarity of *D. reticulata* Link from the Indopacific with the *D. decussata*-group has been mentioned by Rutsch (1930, p. 609, footnote 2).

Occurrence. — N.V.P. Blue No. 3892.

Distribution. — Compare Woodring (1959, p. 206).

Family **BURSIDAE**

Genus **BURSA** Röding

Röding, 1798, Museum Boltenianum, p. 128.

Type species (by subsequent designation, Jousseau, 1881, Soc. Zool. France, Bull., vol. 6, p. 174), *Bursa mammata* Röding.

Subgenus **COLUBRELLINA** Fischer

Fischer, 1884, Manuel de Conchyliologie, p. 656.

Type species (by monotypy), *Ranella candisata* Lamarck.

Bursa (Colubrellina) caelata amphitrites Maury Pl. 68, figs. 12, 13,
Pl. 69, fig. 2

1917. *Bursa amphitrites* Maury, Bull. Amer. Paleont., vol. 5, No. 29, p. 109, pl. 17, fig. 9.

1922. *Bursa amphitrites* Maury, Pilsbry, Acad. Nat. Sci. Philadelphia, Proc., vol. 73, p. 360.

1934. *Bursa (Marsupina) albofasciata boussingaulti* Rutsch, Abh. Schweiz. Pal. Ges., Bd. 54, p. 58, pl. 3, figs. 3, 4, text-fig. 7.

1959. *Bursa (Colubrellina) caelata amphitrites* Maury, Woodring, U.S. Geol. Sur., Prof. Paper, 306-B, p. 207, pl. 28, figs. 1, 2, 7, 8.

Shell of medium size. Spire moderately high. Whorls strongly inflated and shouldered. Varices nearly in one plane, except the two last ones. Protoconch consists of a little more than three volutions, separated from the first sculptured whorl by a conspicuous oblique line, the upper end of which lies in the plane of the early varices. The sculpture starts with a spiral carrying seven or eight knobs which forms the shoulder on later whorls. In addition a few other faint spirals are indicated, and on the posterior half of the

whorl some axial ribs are present corresponding in number to the knobs on the main spiral. On succeeding whorls the shoulder spiral becomes strong and double, and the number of minor spirals increases. There are three or four intervarical knobs on the shoulder. The numerous closely spaced spirals of various size on the body whorl are knobby throughout. Suture deep. Aperture oval. Outer lip with denticles. Denticles of inner lip narrow and long, irregularly placed. Posterior canal curved towards outer lip. Siphonal canal short, bent backwards and slightly towards the outer lip.

Type. — Cornell University, No. 36819.

Remarks. — Maury's original figure shows more knobs on the shoulder spiral than on the present specimens. But this feature is considered to fall within the variability. The shells at hand stand closer to Woodring's figures which have a less inflated body whorl. The types of Rutsch's *B. albofasciata boussingaulti* from the Punta Gavilán formation are available. They agree well with the shells from Paraguaná, except that the spiral sculpture is somewhat less accentuated. Only their shoulder spire is doubled, but not others below it as it is the case on the present specimens. One of the paratypes has an excellently preserved protoconch and first sculptured whorl (compare Pl. 69, fig. 1). Woodring's description of the protoconch and the first sculpture fits exactly to this specimen but not quite to those from Paraguaná thus showing that already the first sculpture cannot be considered as a constant systematic criterion.

Comparisons. — This species has been compared with *B. corrugata* (Perry) and *B. cubaniana* (d'Orbigny). The Recent *B. thomae* (d'Orbigny) (figured in Abbott, 1958, pl. 1, fig. j, and in Warmke and Abbott, 1961, 1962, pl. 18, fig. j) seems to be closely related to *B. caelata amphitrites*. Its posterior canal is more bent towards the outer lip, but the figures at hand do not allow further remarks.

Occurrence. — N.V.P. Blue No. 3892, Re 1152, Re 1199.

Distribution. — Cercado and Gurabo formations, Dominican Republic. Gatún formation, Panamá Canal Zone. Punta Gavilán formation, Venezuela.

Family **TONNIDAE**

Genus **MALEA** Valenciennes

Valenciennes, 1832, *in* Humboldt and Bonpland, Voyage aux régions équinoxiales du nouveau continent; Recueil d'observations de zoologie et d'anatomie comparée, vol. 2, p. 324.

Type species (by subsequent designation, Herrmannsen, 1847, *Indicis generum malacozoorum primordia*, vol. 2, p. 13), *Malea latilabris* Valenciennes (= *Cassis ringens* Swainson).

Malea cf. camura Guppy

1866. *Malea camura* Guppy, Quart. Jour. Geol. Soc. London, vol. 22, p. 287, pl. 17, fig. 9.

Remarks. — There is but a single, apparently immature, poorly preserved specimen (H 13701) of this form. It is a cast with some fragments of the shell preserved. These fragments carry somewhat narrower spiral ribs than the well-preserved specimens of *M. camura* from Bowden, Jamaica, at hand. Its height: 31 mm. Aperture, inner and outer lips not preserved.

The holotype of *M. camura* [British Museum (Natural History) No. 64076, Coll. Guppy] has been refigured by Pflug, 1961, (pl. 10, figs. 3, 6). Unfortunately its anterior part is broken and probably lost now.

Occurrence. — Re 1154.

Family **FICIDAE**

Genus **FICUS** Röding

Röding, 1798, Museum Boltenianum, p. 148.

Type species (by tautonymy and subsequent designation, Winckworth, 1945, *Malac. Soc. London, Proc.*, vol. 26, p. 140), *Ficus variegata* Röding (= *Bulla ficus* Gmelin = *Murex ficus* Linné).

Ficus carbasea carbasea (Guppy)

Pl. 69, figs. 3-5

1866. *Ficula carbasea* Guppy, Quart. Jour. Geol. Soc. London, vol. 22, p. 580, pl. 26, fig. 7.

1910. *Ficula carbasea* Guppy, Guppy, Agr. Soc. Trinidad and Tobago, Soc. Paper 440, p. 10 (Reprint, Harris, 1921, *Bull. Amer. Paleont.*, vol. 8, No. 35, p. 152).

1922. *Pyrula carbasea* Guppy, Pilsbry, Acad. Nat. Sci. Philadelphia, Proc., vol. 73, p. 364.

1925. *Pyrula trinitaria* Maury, *Bull. Amer. Paleont.*, vol. 10, No. 42, p. 222, pl. 41, figs. 9, 12.

1925. *Pyrula carbasea* Guppy, Maury, *ibid.*, p. 224, pl. 41, fig. 5.

1929. *Ficus colombiana* Anderson, Cal. Acad. Sci., Proc., 4th ser., vol. 18, No. 4, p. 143, pl. 13, figs. 1, 2.
1934. *Ficus aff. ventricosa* (G. B. Sowerby I), Rutsch, Abh. Schweiz. Pal. Ges., Bd. 54, p. 62, pl. 3, fig. 8, text-fig. 8.
1938. *Ficus carbasca* (Guppy), Vokes, Amer. Mus. Novitates, No. 988, p. 26.
1942. *Ficus carbasca* (Guppy), Rutsch, Verh. Naturf. Ges. Basel, Bd. 54, p. 144.
1959. *Ficus carbasca carbasca* (Guppy), Woodring, U.S. Geol. Sur., Prof. Paper 306-B, p. 211, pl. 36, figs. 10, 13.
1960. *Ficus colombiana* Anderson, Barrios, Bol. Geol., vol. 6, Nos. 1-3, Informe No. 1082, p. 278, pl. 9, fig. 7.

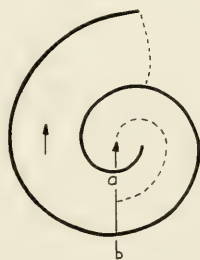
Shell of medium size. Spire low. Protoconch consists of $2\frac{1}{4}$ smooth whorls. Sculpture starting with minute spiral threads, which are crossed soon by oblique lines. These lines abruptly turn into an axial direction after a short distance. This point of directional change of the axial sculpture at the same time seems to mark the point, where the shell axis of the protoconch plus a part of the first sculptured whorl on one hand, and the axis of the remaining whorls on the other hand, meet at an oblique angle. This angle is not constant. Adult sculpture consists of three to seven spirals between the primaries. Area between the primaries slightly concave. Towards the columella the primaries turn to a more or less axial direction, and, especially on larger specimens, become somewhat irregular, and have less secondary and tertiary threads. Siphonal canal broad and long. Columella more or less curved at about the middle of the height of the shell.

Type.—U.S. Nat. Mus. No. 115509.

Remarks.—The variation of the number of secondary and tertiary spirals between the primaries has already been discussed by Rutsch (1942, p. 144) and Woodring (1959, p. 212). The present specimens (about 40) (the great majority of which are in an excellent state of preservation) show three, five or seven spirals between the primaries. This is a real variation, since there are small (height 27.5 mm.) (H 13702) specimens with seven spirals and larger ones (height 48.5 mm.) (H 13703) with three spirals only between the primaries. However, larger specimens tend to have seven or at least five of them, and smaller ones three. Thus the number of secondaries and tertiaries does not seem to be in relation to the age of an individual.

The largest specimen (H 13704) (siphonal canal broken, height 68 mm.) has five whorls in all. Most of the other specimens, from the smallest ones over any intermediate size to the largest ones, have $4\frac{1}{2}$ to 5 volutions. Therefore they must be adult or nearly so (outer lip mostly broken).

The number of nuclear whorls is not constant. Text-figure 3 shows the manner in which the nuclear whorls have been counted. Fourteen (of the 23 well-preserved) protoconchs have $2\frac{1}{4}$ volutions, five have $2\frac{1}{2}$ volutions, and four have only two. The specimens from Springvale described by Rutsch (1942, p. 144) show only two volutions or even somewhat less than two. Woodring (1959, p. 211) indicates "about $1\frac{1}{2}$ " for specimens from the Panamá Canal Zone. Smith (1907, p. 217) stated that the number of volutions decreases from older times to Recent. A Recent specimen of *F. ventricosa* (G. B. Sowerby I) at hand has $1\frac{1}{2}$ volutions. Summarizing the above remarks I believe that there is an astonishing variability in this species. This feature leads one to the supposition that *F. carbacea micronemata* (Brown and Pilsbry) = *Pyrula peruviana* Spieker (fide Woodring 1959, p. 212) might be synonymous with *F. carbacea* s.str. *F. carbacea micronemata* essentially is a smaller subspecies of *F. carbacea* s.str. Its nuclear whorls are not known. It is recorded from the early Miocene and possibly Oligocene of the Panamá Canal Zone. However, only an examination of the type material could bring one nearer to the answer of this question.



Text-fig. 3. Scheme showing how volutions are counted. (after Ehrmann 1933, p. 21, fig. 12). a: starting point. b: one volution completed.

A cast of a paratype of *F. colombiana* Anderson at hand strongly suggests its synonymy with *F. carbacea* s.str.

Comparisons.—*F. carriacouensis* Trechmann (1935, p. 543, pl. 21, fig. 16) from the Miocene of Carriacou is more contracted

anteriorly than *F. carbacea*, according to Trechmann. The description is not detailed enough, and the figure of the type is too poor as to allow a better comparison. The Recent *F. ventricosa* (G. B. Sowerby I) differs in three features from *F. carbacea* s.str.: 1. The protoconch consists of $1\frac{1}{2}$ to $1\frac{3}{4}$ volutions instead of $2\frac{1}{4}$; 2. The shell is much larger and; 3. The primary spirals are much more accentuated. Among the specimens described by Rutsch as *F. aff. ventricosa* (1934, p. 62) there is one reaching the size of Recent individuals. The same is true of the largest shell from Paraguaná. *F. pilsbryi* (Smith) (1907, p. 213, text-fig. 1, pl. 17, fig. 4) has less than two nuclear whorls but otherwise has a similarly shaped shell. It is somewhat less constricted anteriorly, and the columella is less curved. *F. hoveyi* (Maury) (1920, p. 60, pl. 8, fig. 3; pl. 9, fig. 7) and *F. paraensis* White (1887, p. 192, pl. 11, figs. 4, 5) have a higher spire. Their nuclear whorls are unknown.

Occurrence.—N.V.P. Blue No. 3892, Re 1148, Re 1153, Re 1155. Re 1199.

Distribution — See Woodring (1959, p. 212).

Family **MURICIDAE**

Genus **MUREX** Linné

Linné, 1758, Systema Naturae, ed. 10, p. 746.

Type species (by subsequent designation, Montfort, 1810, Conchyliologie systématique, vol. 2, p. 619), *Murex pecten* Montfort (= *Murex tribulus* Linné).

Subgenus **MUREX** s.str.

Murex (Murex) recurvirostris quirosensis F. Hodson Pl. 69, fig. 7

1931. *Murex recurvirostris quirosensis* F. Hodson, in Hodson and Hodson, Bull. Amer. Paleont., vol. 16, No. 59, p. 37, pl. 20, figs. 1, 2, 5.

1934. *Murex recurvirostris quirosensis* F. Hodson, Rutsch, Abh. Schweiz. Pal. Ges., Bd. 54, p. 65.

Shell of medium size. Protoconch only partly preserved. Early whorls sculptured by equally spaced axial ribs of equal size which are crossed by some spiral threads. With increasing age three of these ribs become larger than the others and finally form the varices. They carry a spine on the shoulder of the whorl. There are two or three axial ribs between them. The spire is relatively high and slender, the whorls not much inflated. Aperture oval with long denticles on the outer lip and a few ones on the basal portion of the inner lip. Siphonal canal carrying one or two spines.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 24104.

Remarks.—There are only seven specimens of this species in the collection, five of which are incomplete. They have only two axial ribs and sometimes a third rudimentary one between the varices. The number of these axial ribs varies from two to five as stated by Woodring (1959, p. 215).

It is unsatisfactory to name this form because of the great variability of some characteristics and the many intergrading forms. There seems to exist a feature, which may prove to be of some reliability: the tendency to develop lower spires with geologically decreasing age.

Specimens of *M. recurvirostris s.str.* from Bowden at hand stand close to this material. They have relatively high spires, moderately inflated whorls, and not such heavy varices as on shells from the Punta Gavilán formation or those figured by Weisbord (1962, pl. 26, figs. 3, 4). Punta Gavilán shells of *M. recurvirostris s.str.* have four or more intervarical ribs, lower spires, and their spines (although broken in most cases) seem to be less prominent. Their whorls are much more inflated than in *M. recurvirostris quirosensis*. Specimens of *recurvirostris s.str.* from the Cercado formation of the Dominican Republic and Water Cay, Panamá, at hand have also more inflated whorls and more pronounced varices. Recent shells have a larger angle between the last varix and the siphonal canal than this fossil form.

It is doubtful, whether *M. recurvirostris quirosensis* should be considered as a distinct subspecies. The height of the spire is similar to that of *M. recurvirostris s.str.* from Bowden or that of the Recent *M. woodringi* Clench and Pérez Farfante (1945, p. 9, pl. 4, figs. 1-3) which is considered by Woodring (1959, p. 215) as a synonym of *M. recurvirostris s.str.*

Comparisons.—There are several subspecies of *M. recurvirostris* which have been discussed by Woodring (1959, p. 214) (*rubidus* and *sallasi*) and Clench and Pérez Farfante (1945, pp. 8-9) (*rubidus*, *delicatus*, *citrinus* and *M. anniae*). If one compares *M. recurvirostris rubidus*, of which I have several specimens from the Coralrock formation (Pleistocene) of Barbados, with Recent specimens of *M. recurvirostris s.str.* from the Coast of Senegal (Western Africa), it is difficult to find any difference except the colour. The

Barbados shells are white, the African specimens have some brownish and reddish spiral bands. *M. domingensis* G. B. Sowerby 1 (1850, p. 48, pl. 10, fig. 5) is a similar but larger species. Pflug's figures (1961, pl. 10, figs. 7-13) show specimens with heavy varices and inconspicuous spines. The shell figured by Rutsch (1934, pl. 4, fig. 2) from the Punta Gavilán formation measures 72 mm. in length. *M. cailleti* Petit (1856, p. 87; Clench and Pérez Farfante 1945, p. 17, pl. 9, figs. 3-6) has a similar general sculptural pattern but differs in having the siphonal canal strongly bent backwards. *M. antillarum* Hinds (1844a, p. 126) is a species with a high spire and numerous long spines.

Occurrence.—N.V.P. Blue No. 3892, Re 1148.

Distribution.—Hodson's locality No. 6 (Quiroz), State of Zulia, Venezuela (lower Miocene).

Murex (*Murex*) *polynematicus* Brown and Pilsbry

Pl. 69, fig. 6

1911. *Murex polynematicus* Brown and Pilsbry, Acad. Nat. Sci. Philadelphia, Proc., vol. 63, p. 353, pl. 26, fig. 1.

1959. *Murex* (*Murex* ?) *polynematicus* Brown and Pilsbry, Woodring, U.S. Geol. Sur., Prof. Paper 306-B, p. 215, pl. 36, figs. 2, 3; pl. 37, figs. 6, 9.

Type.—Acad. Nat. Sci. Philadelphia, No. 1719.

Remarks.—There is a single specimen of this species. It agrees well with the original description and Woodring's enlarged redescription which also includes some points of variability. A few differing details fall within this variability. The outer lip of the shell with its scalloped margin projects a little in front of the last varix. The row of denticles situated towards the interior of the aperture is conspicuous. The few denticles near the base of the inner lip are strong. Siphonal canal broken for the greater part.

Comparisons.—Woodring compared *M. polynematicus* with the Recent *M. chrysostoma* G. B. Sowerby I. I have a specimen of this species from the Cabo Blanco Pliocene near La Guaira. Its varices are broader and more prominent but without spines. They are developed already in early stages which is not the case in *M. polynematicus*. The relations with *M. dasus* Gardner (1947, p. 518, pl. 53, fig. 4) from the Chipola formation of Florida have also been discussed by Woodring.

Occurrence.—N.V.P. Blue No. 3892.

Distribution.—Gatún formation, Panamá Canal Zone.

Subgenus **CHICOREUS** Montfort

Montfort, 1810, *Conchyliologie systématique*, vol. 2, p. 611.

Type species (by monotypy), *Chicoreus ramosus* Montfort (= *Murex brevifrons* Lamarck).

Murex (Chicoreus) cf. brevifrons Lamarck

1822. *Murex brevifrons* Lamarck, *Anim. sans Vert.*, vol. 7, p. 161.

Remarks.—There are two apparently young specimens (H 13709/1-2) which might belong to this species. One of them agrees perfectly with the figure given by Maury (1917, pl. 16, fig. 10) for *M. cornurectus* Guppy, which is placed in the synonymy of *M. brevifrons* by Woodring (1959, p. 216). The present specimens have one prominent and a less distinct intervarical axial ribs. The last varix carries six, and the siphonal canal two or three spines.

Comparisons.—*M. florifer* Reeve (1846, *Conch. Icon.*, vol. 3, *Murex*, pl. 36, fig. 188) (= *M. rufus* Lamarck) superficially is close to *M. brevifrons*. The differences between the two species pointed out by Clench and Pérez Farfante (1945, p. 34) are not observable on this material, because protoconch and opercula are missing. *M. florifer* seems to have only one intervarical rib. The form described and figured as *M. rufus* by Gardner (1948, p. 218, pl. 29, fig. 23) from Sanibel Island (West Florida) has a rudimentary second one. Its aperture is circular, whereas those of these shells are oval.

Occurrence.—N.V.P. Blue No. 3892.

Subgenus **SUBPTERYNOTUS** Olsson and Harbison

Olsson and Harbison, 1953, *Acad. Nat. Sci. Philadelphia*, Monograph No. 8, p. 246.

Type species (by original designation), *Murex textilis* Gabb.

Murex (Subpterynotus) textilis Gabb

Pl. 69, figs. 8, 10

1873. *Murex (Pteronotus) textilis* Gabb, *Amer. Philos. Soc., Trans.*, new ser., vol. 15, p. 202.

1890. *Murex (Pteronotus) textilis* Gabb, *Dall, Wagner Free Inst. Sci., Trans.*, vol. 3, pt. 1, p. 142, pl. 9, fig. 4.

1922. *Murex (Pteropurpura) textilis* Gabb, *Pilsbry, Acad. Nat. Sci. Philadelphia, Proc.*, vol. 73, p. 353, pl. 28, fig. 4.

1953. *Murex (Subpterynotus) textilis* Gabb, Olsson and Harbison, *Acad. Nat. Sci. Philadelphia, Mon.* 8, p. 247, pl. 36, figs. 7, 7a.

Type.—*Acad. Nat. Sci. Philadelphia*, No. 3257.

Remarks.—This species is represented in the collection by a single well-preserved specimen. It differs from the type as figured

by Pilsbry (1922, pl. 28, fig. 4) in that the varix surrounding the outer lip is more constricted towards the base of the anterior canal. It does not seem justified to fix this feature with a subspecific name.

Occurrence.—N.V.P. Blue No. 3892.

Distribution.—Miocene of the Dominican Republic. Pliocene of Florida.

Subgenus **SIRATUS** Jousseau

Jousseau, 1880, *Le Naturaliste*, vol. 1, No. 42, p. 335.

Type species (by monotypy), *Murex senegalensis* Gmelin.

***Murex (Siratus ?) triangularis*, n.sp.**

Pl. 69, fig. 9;
Pl. 70, figs. 1, 2

Shell of small to medium size. Spire high. Whorls about seven. Protoconch consists of $1\frac{1}{2}$ volutions. First sculpture composed of equally sized axial ribs and three spirals on the lower half of the whorls, and two less distinct ones below the posterior suture. Number of axial ribs per whorl decreases from nine in early stages to six in late stages. With increasing age the whorls become prominently shouldered. The last and the penultimate whorls carry three varices with a spine on their shoulder. There is a single knoblike axial ridge between them. Except a few small processes on the varices formed by the spirals there are no other spines below and above the shoulder. Already in young stages the number of spiral threads becomes larger. On the last whorl there are eight to ten primary spirals below the shoulder with three to five secondary threads of different size in their interspaces. Suture sharply incised in late stages but inconspicuous on early whorls. The outer lip carries a row of denticles at some distance of its margin. The anteriormost one is in connexion with a more or less conspicuous ridge forming the outer margin of the siphonal canal. The inner lip is smooth, and its edge is not erect. Siphonal canal short and broad. A small, slitlike umbilical opening is present between the inner margin of the siphonal canal and a former siphonal canal. Aperture oval.

Holotype.—Basel Natural History Museum, No. H 13711.

Dimensions of holotype.—Height 40.1 mm., greatest diameter 24.2 mm.

Variability.—The spines on the shoulder are generally developed on the last three varices only. Sometimes they are present on

the penultimate whorl also. The denticles on the outer lip may be somewhat elongate or have the form of a knob. The other characters are constant.

Remarks.—The material consists of the holotype and six paratypes. It is doubtful whether this species belongs to the subgenus *Siratus*. The three varices per whorl are present on the two last volutions only. On earlier whorls the axial sculpture consists of ribs which are more numerous than later on. According to Clench and Pérez Farfante (1945, p. 24) this subgenus differs from *Murex s.str.* mainly by its broad and short siphonal canal. The type species *M. senegalensis* Gmelin has more numerous spines, and the siphonal canal is less opened towards the aperture. I have not found any form comparable to this species.

Occurrence.—N.V.P. Blue No. 3892.

Genus **PAZIELLA** Jousseaume

Jousseaume, 1880, *Le Naturaliste*, vol. 1, No. 42, p. 335.

Type species (by monotypy), *Murex pazi* Crosse.

Subgenus **PANAMUREX** Woodring

Woodring, 1959, U.S. Geol. Sur., Prof. Paper 306-B, p. 217.

Type species (by original designation), *Murex (Phyllonotus) gatunensis* Brown and Pilsbry.

Paziella (Panamurex ?) cf. gatunensis (Brown and Pilsbry)

Pl. 69, figs. 11, 12

1911. *Murex (Phyllonotus) gatunensis* Brown and Pilsbry, Acad. Nat. Sci. Philadelphia, Proc., vol. 63, p. 354, pl. 26, fig. 2.

Shell of medium size. Seven varices per whorl with a short spine on the shoulder. Spirals strong with tertiary threads and sometimes secondary spirals between them. There is an opened narrow umbilicus between siphonal fasciole and inner side of siphonal canal.

Remarks.—There is a single specimen which may belong to this species. Its protoconch, the first sculptured whorls, and the last varix are broken. The inner lip is partly preserved and shows in its lower portion a few denticles. The long denticles of the outer lip are still visible within the aperture. The forward-directed extensions on the varices below the shoulder of the body whorl are rudimentary. The specimen seems to be an immature shell, the spines on the shoulders being but weakly developed. A young

specimen has been figured by Woodring (1959, pl. 35, figs. 9, 10).

Comparisons.—*P. fusinoides* Gardner (1947, p. 524, pl. 52, figs. 39, 42) from the Chipola formation of Florida is similar to this specimen. The varices are broader and rounded in the Floridian species and its spines less conspicuous, both characteristics of *Dallimurex* (see Rehder, 1946, p. 142). "*Muricopsis*" *laccopoia* Gardner (1947, p. 529, pl. 52, figs. 40, 41) is a synonym of *P. fusinoides* as stated by Woodring (1959, p. 217). "*Muricidea*" *clarksvillensis* Mansfield (1937b, p. 610, pl. 85, fig. 6) and "*Muricidea*?" *alaquaensis* Mansfield (1935, p. 39, pl. 3, fig. 9; pl. 4, fig. 10) may belong to *Dallimurex*. They seem to be close to *P. fusinoides*.

Occurrence.—N.V.P. Blue No. 3892.

Genus **EUPLEURA** H. and A. Adams

H. and A. Adams, 1853, The genera of Recent Mollusca, vol. 1, p. 107.

Type species (by subsequent designation, Baker, 1895, Chicago Acad. Sci., Bull., vol. 2, p. 176), *Ranella caudata* Say.

Eupleura kugleri, n.sp.

Pl. 70, figs. 3-6

Shell of medium size. Spire high. Whorls moderately inflated, about seven in number. Protoconch and surface of first sculptured whorls not well preserved. Protoconch probably consists of about $1\frac{1}{2}$ volutions. Axial sculpture formed by regularly spaced ridges in early stages, two of which are transformed on later whorls into sharp, nearly opposite varices. Between the varices there are generally three axially elongate knobs, which, however, may be absent. Early whorls sculptured by two prominent spirals, the upper one marking a shoulder. Subsequently secondary spirals are intercalated. On the body whorl the shoulder disappears. Body whorl with about seven primary spirals which form projections at the margin of the outer lip. Their interspaces are smooth or have inconspicuous minor spirals. Suture slightly appressed. Aperture oval. Outer lip with a row of six denticles at a short distance from its margin. Inner lip smooth. Siphonal canal moderately broad, slightly bent backwards, short.

Holotype.—Basel Natural History Museum, No. H 13715.

Dimensions of holotype.—Height 24.1 mm., greatest diameter 14.4 mm.

Remarks.—The material consists of the holotype and four paratypes. The holotype may be an adult shell, but the paratypes are immature. Two of them (H 13718/1-2) have only one varix, the preceding rudimentary ones being developed as axial ribs only.

Comparisons.—Next to this species is *E. thompsoni* Woodring (1959, p. 218, pl. 36, figs. 6-9) from the Gatún formation of the Panamá Canal Zone. *E. thompsoni* is a larger species; it has a 2½-whorled protoconch, a lower spire, and differs in the intensity of the spiral sculpture on the body whorl. The whorls are generally more inflated. *E. miocenica* Dall (1890, p. 146, pl. 12, fig. 9) is different from *E. kugleri* like other northern forms mentioned by Woodring (1959, p. 219). Its varices are less prominent, the spire lower, and the margin of its inner lip is erect. The Recent *E. nitida* (Broderip) (1832, p. 179) from the Pacific Coast, which has been figured by Keen (1960, fig. 365), has about the same dimensions, a similar height of the spire, but also an erect inner lip.

Occurrence.—N.V.P. Blue No. 3892, Re 1148.

Genus **TYPHIS** Montfort

Montfort, 1810, *Conchyliologie systématique*, vol. 2, p. 615.

Type species (by original designation), *Murex tubifer* Roissy (= *Purpura tubifer* Bruguière).

Subgenus **LAEVITYPHIS** Cossmann

Cossmann, 1903, *Essais de paléoconchologie comparée*, pt. 5, p. 59.

Type species (by original designation), *Typhis coronarius* Deshayes.

Typhis (Laevityphis) sawkinsi Mansfield

Pl. 70, figs. 7, 8

1925. *Typhis sawkinsi* Mansfield, U.S. Nat. Mus., Proc., vol. 66, art. 22, p. 48, pl. 2, fig. 11.

1925. *Typhis linguiferus* Maury, Bull. Amer. Paleont., vol. 10, No. 42, p. 214, pl. 36, figs. 4, 5. Not of Dall.

1944. *Laevityphis (Laevityphis) sawkinsi* (Mansfield), Keen, Jour. Pal., vol. 18, No. 1, pp. 59, 67.

Shell slender. Protoconch with nearly three smooth volutions, strongly shouldered near their upper suture. Sculpture of adult shell composed of four varices per whorl alternating with tubes. The varices are produced at their upper end and somewhat bent in an antispiral direction. The tubes, situated approximately half-way between two varices, are bent outwards and also slightly in an antispiral direction. Their anterior continuation is a ridge

extending down to the base of the whorl. The area between the appressed, undulating suture and the shoulder of the whorl is concave. The varices are connected with the preceding tube by a sharp ridge accentuating the shoulder of the whorl. The growth lines are extremely faint and the three or four spiral threads only feebly indicated. There is a single periodically reappearing conspicuous growth line between a tube and its preceding varix. The closed siphonal canal is bent to the right. Aperture ovate and bordered by a thin, raised wall.

Type.—U.S. Nat. Mus., No. 352673.

Remarks.—The material is not quite identical with two specimens from Trinidad at hand. One of them has more conspicuous varices and comparatively smaller ridges below the tubes. The other specimen is more slender, *i.e.* its tubes and varices are closer set.

Comparisons.—Closest related to *T. sawkinsi* is *T. linguiferus* Dall (1890, p. 152, pl. 12, fig. 7) from the Chipola formation of Florida. Dall's original figure corresponds well with this specimen. The only differences to *T. sawkinsi* seem to be the more accentuated growth lines and spiral threads. *T. costaricensis* Olsson (1922, p. 132, pl. 10, figs. 22, 29; not 1942, p. 76, pl. 12, figs. 5, 8; see Keen, 1943, p. 54) from the Gatún formation of Costa Rica is said to differ from *T. linguiferus* by its "uniformly smaller size and in nearly lacking the spine-like process on the shoulder of primary varices."

Occurrence.—N.V.P. Blue No. 3892, Re 1193.

Distribution.—This species is recorded hitherto from Trinidad only: "Guaico-Tamana Road, mile 13." This locality has the coordinates N 335.300 links; E 508.400 links, and is at the top of the *Globigerinatella insucta* Zone of the Brasso formation (personal information from H. G. Kugler). Radix point: Trinity Hill sandstone member of the Moruga formation (Rutsch, private report).

Family **THAIDIDAE**

Genus **CYMIA** Mörch

Möorch, 1860, Malakozoologische Blätter, Bd. 7, pp. 97, 98.

Type species (monotype of *Cuma* Swainson), *Cuma sulcata* Swainson (= *Buccinum tectum* Wood). See Woodring (1959, p. 223).

Cymia buchivacoana cantaurana H. K. Hodson

Pl. 70, fig. 9

1931. *Cymia buchivacoana cantaurana* H. K. Hodson, in Hodson and Hodson, Bull. Amer. Paleont., vol. 16, No. 60, p. 11, pl. 10, fig. 1.

Shell large and heavy. Nuclear whorls not preserved. Young whorls ornamented by a carina near the anterior suture and two or three spirals, which are crossed by straight growth lines somewhat oblique to the shell axis dividing them into numerous single but closely set knobs. With increasing age the growth lines become less distinct and slightly sinused. In late stages the numerous spirals are broad and flat, both posterior and anterior to the carina, which now carries coarse spines. Outer lip not thickened. Its interior sculptured by conspicuous spiral ridges. Anal fasciole deepest near outer lip. Siphonal canal deep. The uppermost part of the columella carries a thickening of the callus, corresponding in length to the sinus of the outer lip near the adapical end of the aperture. Columellar fold indistinct at aperture but more accentuated towards the interior.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 24147.

Remarks.—The material consists of three well-preserved adult specimens. The horizontal and vertical distribution of the genus *Cymia* has been discussed by Woodring (1959, pp. 223-224).

Comparisons.—This species with its strongly developed carina represents an extreme form. The differences between it and *C. buchivacoana* H. K. Hodson have been pointed out in the original description. *C. cheloma* Woodring (1959, p. 223, pl. 28, figs. 12, 15) from the Gatún formation of the Panamá Canal Zone has been compared with *C. buchivacoana* by Woodring.

Occurrence.—N.V.P. Blue No. 3892.

Distribution.—Known from type locality only.

Cymia cocoditana H. K. Hodson

Pl. 71, figs. 1, 2, 5, 9

1931. *Cymia cocoditana* H.K. Hodson, in Hodson and Hodson, Bull. Amer. Paleont., vol. 16, No. 60, p. 11, pl. 8, fig. 2; pl. 9, fig. 4.

Shell of medium size, solid. Protoconch missing. Young whorls sculptured by three spirals, the middle one of which develops into a carina. The spirals are crossed by nearly axial ribs causing knobs at the intersection points with the spirals. The carina is situated on the lower third of the whorl. In later stages the axial sculptural

element becomes less distinct and somewhat sinused, whereas the carina carries gradually more prominent spines, which generally are elongate in the spiral direction. The spiral sculpture below the carina is more accentuated than that above it. On the body whorl it consists of numerous spirals of different width and interspaces. The outer lip is crenulated and not thickened. There are a few short spiral ridges on its interior side. The anal fasciole generally well developed on a part of the body whorl. Adapical sinus of outer lip deep. Just below it there is a thickening of the callus in form of a ridge, which extends into the aperture. Columellar fold not distinct at aperture but towards the interior. Siphonal canal recurved. Lamellar siphonal fasciole strongly developed. Area between it and carina very concave.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 24142.

Variability.—Judging from the 19 specimens at hand the main variable features are: 1. Intensity and shape of spines; 2. Intensity of development of anal fasciole. Specimens with spines directed downwards generally have a more convex upper part of the body whorl thus causing a different general aspect. Other specimens have only weakly developed spines. The body whorl then appears rounded.

Comparisons.—*C. henekeni* Maury (1917, p. 104, pl. 17, fig. 1) has only weak spines. The spiral sculpture above the carina is more accentuated on the specimen figured by Maury (immature individual?), and the anal and siphonal fascioles are less developed than in *C. cocoditana*. The spire is lower and the carina of the younger whorls less accentuated. *C. henekeni tectiformis* Pilsbry (1922, p. 355, pl. 28, figs. 11, 12) also has a lower spire, and the upper portion of the body whorl is somewhat concave. The holotype of *C. pilsbryi* Olsson (1932, p. 182, pl. 19, fig. 2) from the lower Zorritos formation of Perú is a poorly preserved specimen. It seems to differ from *C. cocoditana* by a straight siphonal canal and a differently proportioned body whorl. *C. brightoniana* Maury (1925, p. 215) from the Pliocene of Trinidad mainly differs from *C. cocoditana* by a secondary spiral set of spines on the body whorl below the primary one. Hertlein and Jordan compare their *C. heimi* (1927, p. 627, pl. 18, fig. 5) from the Isidro formation of Lower California with *C. henekeni tectiformis*. *C. heimi* is distinguished

from *C. cocoditana* by its more flat-sided spire and a less conspicuous siphonal fasciole.

Occurrence.—N.V.P. Blue No. 3892.

Distribution.—Known from type locality only.

Family **PYRENIDAE**

Genus **MITRELLA** Risso

Risso, 1826, *Histoire naturelle des principales productions de l'Europe méridionale*, vol. 4, p. 247.

Type species (by subsequent designation, Cox, 1927, Report Paleontology Zanzibar, Moll., p. 28), *Mitrella flaminea* Risso (= *Murex scriptus* Linné).

The genus *Mitrella* is used here in a broad sense. *M. quirosana* would fall under *Columbellopsis* Bucquoy, Dautzenberg, and Dollfus as redefined by Woodring (1928, p. 274). Grant and Gale (1931, p. 689) placed *Columbellopsis* in the synonymy of *Mitrella*. Gardner (1947, p. 592) emphasized the difficulty of separating *Columbellopsis* as a supra-specific unit from *Mitrella*.

Mitrella quirosana (H. K. Hodson)

Pl. 71, figs. 3, 4

1931. *Strombina quirosana* H. K. Hodson, in Hodson and Hodson, Bull. Amer. Paleont., vol. 16, No. 59, p. 27, pl. 10, figs. 12, 13.

Shell small. Protoconch consists of about two smooth and moderately convex volutions. Spire whorls six in number, straight-sided, smooth. Suture linear, well defined. Body whorl constricted at base, where it is sculptured by a few spirals. Outer lip strongly thickened, projecting over a part of the penultimate whorl; with denticles on inner surface. Callus of inner lip detached from pillar, carrying a few denticles, which are smaller than those of the outer lip. Callus thickened near posterior end of aperture forming a short canal together with the outer lip. Siphonal canal short and broad.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 24070.

Remarks.—This species is represented by seven specimens. Hodson indicated eight postnuclear whorls in the original description, but according to her figure the holotype has only six of them like the specimens from Paraguaná. These shells reach a considerably larger size than the holotype.

Comparisons.—*M. lepta* Woodring (1928, p. 275, pl. 16, fig. 15) from Bowden, Jamaica, is a smaller species, has a smaller

apical angle, and a less bulging body whorl. *M. perfervida* Dall (1900, p. 1197, pl. 41, fig. 10; Gardner, 1947, p. 510) from the Chipola formation and the Oak Grove sand of Florida is larger, has a different protoconch, and its outer lip is much more sharply bent towards the siphonal canal. Gardner (1947) described a number of species of *Mitrella* from the Alum Bluff group of Florida. Most of those forms are smaller than the specimens from Paraguaná or do not have the characteristic straight-sided whorls of *M. quirosana*.

Occurrence.—N.V.P. Blue No. 3892.

Distribution.—Known from type locality (Hodson's locality No. 6, Quiroz) only (lower Miocene).

Family BUCCINIDAE

Genus CYMATOPHOS Pilsbry and Olsson

Pilsbry and Olsson, 1941, Acad. Nat. Sci. Philadelphia, Proc., vol. 93, p. 33.

Type species (by original designation), *Cymatophos galerus* Pilsbry and Olsson.

Cymatophos cocoditoensis (F. Hodson)

Pl. 71, figs. 6-8

1931. *Phos* (*Antillophos*) *cocoditoensis* F. Hodson, in Hodson and Hodson, Bull. Amer. Paleont., vol. 16, No. 59, p. 35, pl. 17, figs. 2-4.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 24094.

Variability.—The material consists of more than 150 specimens originating from near the type locality. The great variability of this species is due mainly to two variable features: the strength of the axial ribs and their frequency. In typical specimens the thickened outer lip is followed after a quarter of a revolution by a strong varix. The rest of the shell carries about equidistant axial ribs of equal strength. Many specimens, however, have (at least on later whorls) irregularly placed axials of different size. There is a tendency to reduce the axial sculpture on the last two whorls, thus approaching *C. paraguayensis*. The apical angle is also somewhat variable.

Remarks.—*C. cocoditoensis* and *C. paraguayensis* have identical early stages. Their differences are developed on later whorls only. The protoconch of both species has about three revolutions. The first sculpture consists of two spirals and eight to nine axial ribs per whorl. Already on the first sculptured whorl secondary

spirals are intercalated, and a subsutural spiral is developed. The somewhat biangulated early whorls become rounded subsequently. Adult whorls carry about six primary spirals and a few secondaries. Typical shells of *C. paraguanensis* have some more spirals.

Although all intergrading forms between these two species are found, it seems to be justified to separate them, since their adult stages are clearly distinct in typical shells. *C. paraguanensis* usually has no axial sculpture on the last two or three whorls except a few varices.

Comparisons.—*C. veatchi* Olsson (1922, p. 121, pl. 9, figs. 2, 3), from the Gatún formation of Costa Rica, is a similar species and differs from *C. cocoditoensis* in a few details only. The callus of the inner lip is but poorly developed in the Venezuelan species, and the denticle near the posterior end of the aperture weak or even missing. The sharp ridge bordering the siphonal fasciole is missing in *C. veatchi*, and its axial sculpture is less pronounced. *C. buchivacoensis* F. Hodson (in Hodson and Hodson 1931a, p. 33, pl. 16, figs. 1, 4) from the middle Miocene of Falcón, which is considered a synonym of *C. veatchi* by Woodring (1964, p. 260), has the same sculptural pattern but differs by the development of a shoulder forming a conspicuous angulation on the last whorls. *C. turbacoensis* Anderson (1929, p. 136, pl. 15, figs. 6, 7) from the Colombian Miocene is larger and has a concave and unsculptured area below the suture.

Occurrence.—N.V.P. Blue No. 3892, Re 1148, Re 1153, Re 1154, Re 1155, Re 1199.

Distribution.—Known from type locality only.

Cymatophos paraguanensis (F. Hodson)

Pl. 71, fig 10;
Pl. 72, figs. 1, 2

1931. *Phos* (*Antillophos*) *paraguanensis* F. Hodson, in Hodson and Hodson, Bull. Amer. Paleont., vol. 16, No. 59, p. 36, pl. 17, figs. 1, 5.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 24093.

Remarks.—The material at hand consists of about 100 specimens. The number of typical shells is low (15). See also under *C. cocoditoensis*.

Comparisons.—*C. subsemicostatus* (Brown and Pilsbry) (1911, p. 350, pl. 25, fig. 3) from the Gatún formation of the Panamá Canal Zone seems to be similarly sculptured as *C. paraguanensis*.

The type of this species is imperfect. The specimens figured by Woodring (1964, pl. 41, figs. 1-4) are larger. The axial sculpture on the last whorl is less reduced than in *C. paraguayensis*. *C. hodsoni* Olsson (1932, p. 174, pl. 18, figs. 4, 12) from the early Miocene of Perú is so similar to *C. paraguayensis* that it seems to represent the same species. In any case it will be necessary to compare the type material of both species in order to separate them.

Occurrences.—N.V.P. Blue No. 3892, Re 1148, Re 1152, Re 1155, Re 1199.

Distribution.—Known from type locality only.

Family NASSARIIDAE

Genus **PALLACERA** Woodring

Woodring, 1964, U.S. Geol. Sur., Prof. Paper 306-C, p. 269.

Type species (by original designation), *Nassa myristicata* Hinds.

Pallacera maracaibensis (Weisbord)

Pl. 72, fig. 6

1929. *Potamides maracaibensis* (Williston), Weisbord, Bull. Amer. Paleont., vol. 14, No. 54, p. 38, pl. 8, figs. 8, 9.

1931. *Phos* (*Phos*) *maracaibensis weidenmayeri* F. Hodson, in Hodson and Hodson, Bull. Amer. Paleont., vol. 16, No. 59, p. 30, pl. 13, figs. 1-4.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 22969.

Remarks.—Weisbord based his description on imperfect specimens from Colombia and the Urumaco area, Venezuela. Hodson described specimens from the Urumaco area as a subspecies. The only specimen in this collection, which I refer to this species, exactly agrees with this description.

The strength of the axial ribs does not seem to be constant. The 13 to 14 axial riblets on the early whorls, which are said to be characteristic, may become obsolete. This is demonstrated also by the figured paratype. Three shells at hand, whose riblets are but weakly developed or missing, also have a less shouldered but somewhat more inflated body whorl. They are tentatively referred to *P. urumacoensis*. Four slightly weathered specimens from the Urumaco area at hand show only weak or no axial riblets on the early whorls. Two of them are clearly intermediate forms between *P. maracaibensis* and *P. urumacoensis*. Additional material would perhaps prove that both should be united in one species.

Comparisons.—*P. tuberaensis* (Anderson) (1929, p. 135, pl.

9, figs. 1-3) from the Miocene of Colombia has a spiral sculpture persistent over all the whorls. It is a more slender species and does not have the 14 axial riblets on the early whorls. *Phos venezuelensis* F. Hodson (in Hodson and Hodson, 1931a, p. 31, pl. 15, figs. 3-6) is a smaller species. Its axial ribs are prominent on early whorls already and fewer in number than in *P. maracaibensis*.

Occurrence.—N.V.P. Blue No. 3892.

Distribution.—Miocene of Venezuela and Colombia.

Pallacera urumacoensis (F. Hodson)

Pl. 72, fig. 7

1931. *Phos (Phos) tuberaensis urumacoensis* F. Hodson, in Hodson and Hodson, Bull. Amer. Paleont., vol. 16, No. 59, p. 31, pl. 14, figs. 1, 2.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 24086.

Remarks.—As stated under *P. maracaibensis* this species may prove to be a synonym of *P. maracaibensis* when more material will be available.

Occurrence.—N.V.P. Blue No. 3892.

Distribution.—Miocene of Falcón, Venezuela.

Genus **ANTILLOPHOS** Woodring

Woodring, 1928, Carnegie Inst. Wash., Pub. 385, p. 259.

Type species (by original designation), *Cancellaria candei* d'Orbigny.

Antillophos candei gatunensis (Toula)

Pl. 72, figs. 3, 5

1909. *Phos gatunensis* Toula, Jahrb. k.k. geol. Reichsanstalt, Bd. 58, p. 701, pl. 25, fig. 11; pl. 28, fig. 6.

1964. *Antillophos (Antillophos) candei gatunensis* (Toula), Woodring, U.S. Geol. Sur., Prof. Paper 306-C, p. 264, pl. 42, figs. 3, 4. For additional citations see this publication.

Neotype.—U.S. Nat. Mus., No. 643660.

Remarks.—There are nine specimens of this species. Their protoconchs are missing or not well preserved. Two specimens from the Gatún formation of the Panamá Canal Zone are at hand. The axials and spirals are mostly somewhat broader and less well defined in the material from Paraguaná. The upper two folds on the inner lip generally are prominent, but in a few cases they are weakly developed only. The long ridge near the posterior end of the aperture, which runs somewhat obliquely to the spiral sculpture far into the aperture, is stronger on the shells from Paraguaná than on those from the Panamá Canal Zone.

Comparisons.—*A. gatunensis* has been compared sufficiently with several species: *A. gabbi* (Dall), *A. mexicanus* (Böse) and *A. mexicanus bendrati* (Rutsch). *A. rutschi* (Olsson) (1942, p. 73, pl. 9, fig. 5) from the Pliocene of southwestern Panamá is difficult to separate from *A. mexicanus* with the help of the original figure alone. Both species are considerably stouter than *A. gatunensis*, and *A. rutschi* is said to differ from *A. mexicanus* by its more regular sculpture and stouter shell. The Recent *A. virginiae* (Schwengel) (1942, p. 65, pl. 3, figs. 6, 7), which has been dredged at 65 fathoms off Palm Beach, Florida, has practically the same outline as *A. gatunensis*. The spiral sculpture starts with two spirals, but with four or five in *A. gatunensis*. The axials may become varix-like in *A. virginiae* (see also Brown and Pilsbry's 1911 figure 2 on plate 25), and there are some more denticles on the inner lip.

Occurrence.—N.V.P. Blue No. 3892.

Distribution.—*Fide* Woodring (1964, p. 265).

Antillophos ? aff. landesi (Marks)

Pl. 72, figs. 8, 9

1951. *Tritiaria (Antillophos) landesi* Marks, Bull. Amer. Paleont., vol. 33, No. 139, p. 115, pl. 8, figs. 1, 2.

Remarks.—There are about a dozen shells with protoconchs of about three volutions which superficially resemble *A. landesi* from the Subibaja formation (lower Miocene) of southwestern Ecuador. They have similar dimensions, about the same convexity of the whorls, the same number of spire whorls, and the same sculptural pattern on the early volutions. But they differ constantly in having a longer siphonal canal and a lower number of spirals on the later whorls.

The strength of the axials and spirals of the present specimens is not constant. The axials may be broader than those of the figured specimen; in other cases the spirals form small tubercles at the intersection points with the axials.

Comparisons.—Marks compared *A. landesi* with *A. elegans limonensis* (Olsson) (1922, p. 119, pl. 9, figs. 12, 13) from the Gatún formation of Costa Rica. This species, however, has a completely different protoconch. While the volutions of the protoconch of *A. landesi* and of the shells from Paraguaná are regularly convex, those of *A. elegans limonensis* have an anterior carina divid-

ing the surface into an upper larger, straight to slightly convex area, and a steep anterior slope. *A. peruviana* (Olsson) (1932, p. 171, pl. 18, fig. 10) from the lower Miocene of Perú mainly differs by its weaker axial sculpture and the less inflated whorls. The sculpture of the early spire whorls is exactly the same, but the number of axials on the body whorl generally is lower on the shells from Paraguaná. *A. estrellensis* (Olsson) (1922, p. 120, pl. 9, figs. 17, 18) from the Gatún formation of Costa Rica is larger, more slender, and has more spire whorls. *A. monachus* Woodring (1964, p. 266, pl. 40, figs. 20, 21) from the upper part of the Gatún formation (late Miocene) of Panamá has the same shape, sculptural pattern, and number of spire whorls but is twice as large as *A. aff. landesi*. *Phos blountanus* Mansfield (1935, p. 34, pl. 3, fig. 5) from the *Arca* Zone (upper middle Miocene) of Florida is a more slender species with fewer, but broader, axials and a well-developed callus on the inner lip.

Occurrence.—N.V.P. Blue No. 3892.

***Antillophos* ? spec. A**

Pl. 72, fig. 4

Remarks.—There is a single shell, which has the same general outline and the same sculpture on the early whorls as *A. aff. landesi*. It differs principally, however, in the arrangement of the axial ribs. Like *A. aff. landesi* the first sculptured whorl carries 11 axial riblets. But subsequently the number of axials decreases to nine per whorl, and simultaneously they become considerably wider and rounded, whereas in *A. aff. landesi* their number gradually increases on later whorls. On the last spire whorl and the body whorl the axials of *Antillophos* ? spec. A again become narrower, and closer set, and number 21 on the last turn. In addition the secondary spirals appear at an earlier stage in *A. spec. A*, and are better developed.

Occurrence.—N.V.P. Blue No. 3892.

Family **MELONGENIDAE**

Genus **MELONGENA** Schumacher

Schumacher, 1817, *Essai d'un nouveau système des habitations des vers testacés*, pp. 64, 212.

Type species (by monotypy), *Melongena fasciata* Schumacher (= *Murex melongena* Linné).

Melongena melongena consors (G. B. Sowerby I)

Pl. 72, fig. 11

1850. *Pyrgula consors* G. B. Sowerby I, Quart. Jour. Geol. Soc. London, vol. 6, p. 49.

1961. *Melongena consors* (Sowerby), Pflug, Acta Humboldtiana, ser. geol. et pal., Nr. 1, p. 49, pl. 13, figs. 1-3, 7-10.

1964. *Melongena melongena consors* (Sowerby), Woodring, U.S. Geol. Sur., Prof. Paper 306-C, p. 273, pl. 44, figs. 2, 4, 6, 8. For additional citations see this publication.

Shoulder of whorls generally well elevated over the sutures. Spiral ornamentation well developed on young whorls, but less accentuated on the body whorl, where the growth lines are predominant except towards the lower half of the columella. There are two spiral rows of spines on the shoulder of the body whorl, the lower one being less prominent. A third row of spines is situated on the lower half of the body whorl.

Lectotype. — British Museum (Natural History), No. G 83953.

Variability. — The arrangement and size of the spines is not constant. Already G. B. Sowerby I stated that there may be two or three spine rows on the shoulder. The lectotype figured by Pflug (1961, pl. 13, figs. 2, 3, 9) has one row only, whereas his figure 8 on plate 13 shows three rows. The variation in the number of spine rows of *M. melongena s.str.* has been mentioned by Clench and Turner (1956, p. 167). The intensity of the spiral ribbing is also strongly variable.

Comparisons. — G. B. Sowerby I (1850, p. 49), Olsson (1932, p. 177), Pflug (1961, p. 50) and others have pointed out the difference between *M. melongena consors* and *M. melongena s.str.* *M. melongena s.str.* has been compared with *M. patula* Broderip and G. B. Sowerby I, its Pacific analogue, by Clench and Turner (1956, p. 166 ff.). Anderson (1929, p. 133, pl. 11, figs. 1, 2) described a new form from the Colombian Miocene under the name of *M. propatula*, stating that it differs from both, *M. melongena* and *M. patula*. His holotype has but a few and weak spines. The row near the base is almost missing, a feature otherwise characteristic for *M. patula*. *M. colombiana* Weisbord (1929, p. 43, pl. 7, figs. 2-4) from the Miocene of Colombia does not reach the size of *M. consors*, carries a much more accentuated spiral ornamentation and a thick parietal callus.

Occurrence.—N.V.P. Blue No. 3892, Re 1148, Re 1152, Re 1153, Re 1154, Re 1199.

Distribution.—*Fide* Woodring (1964, p. 274).

Family **FASCIOLARIIDAE**

Genus **FUSINUS** Rafinesque

Rafinesque, 1815, *Analyse de la Nature*, p. 145 (see Woodring, 1928, *Carn. Inst. Wash.*, Pub. 385, p. 256).

Type species (by monotypy), *Murex colus* Linné.

***Fusinus mithras*, n.sp.**

Pl. 72, fig. 10; Pl. 73, figs. 2-4

Shell heavy and large. Protoconch and first sculptured whorls not preserved. Earliest preserved whorls sculptured by seven strong axial swellings, which are crossed by three primary spirals, another relatively strong spiral just below the suture, and about two secondary threads. The median spiral rapidly increases in strength and forms conspicuous prominences when it crosses the axial swellings which number about 10 on the body whorl. On both sides of the median keel spirals of several orders are intercalated. On the body whorl of the holotype they number about 10 above the median keel. Areas on both sides of the median keel straight or somewhat convex. Growth lines slightly prosocline above periphery, parallel to shell axis below it. Siphonal canal nearly straight. Parietal area with thin callus, spiral sculpture shining through. Umbilical opening apparently large. Near the posterior end of the aperture there is a ridge extending into the body whorl. Outer lip angulated by median prominence with numerous lirations on inner surface. Columella with four indistinct folds.

Holotype.—Basel Natural History Museum, No. H 13738.

Dimensions of holotype.—Height 64.4 mm., greatest diameter 32.2 mm.

Remarks.—The material consists of the holotype and two paratypes. None of these specimens is complete. Apices and ends of siphonal canals are broken. They are considered, however, to be sufficiently well preserved in order to be named.

Comparisons.—*F. mithras* is clearly separated from similar forms by its accentuated periphery. In *F. engonius* Woodring (1928, p. 258, pl. 15, fig. 9) from Bowden, Jamaica, the periphery is more rounded, the outer lip not angulated, and the subsutural area is somewhat concave. A topotype of *F. engonius* at hand does

not show the low columellar folds mentioned in the original description. The body whorl of *F. mithras* is more constricted. *F. haitensis* (G. B. Sowerby I) (1850, p. 49; lectotype figured by Pflug, 1961, pl. 12, figs. 6, 8, 11) and *F. henekeni* (G. B. Sowerby I) (1850, p. 49; lectotype figured by Pflug, 1961, pl. 12, figs. 1, 9, 10) both greatly differ by their evenly rounded whorls.

Occurrence.—N.V.P. Blue No. 3892.

Genus **LATIRUS** Montfort

Montfort, 1810, *Conchyliologie systématique*, vol. 2, p. 531.

Type species (by original designation), *Latirus aurantiacus* Montfort (= *Murex gibbulus* Gmelin).

Latirus (subgenus ?) cf. **tumbeziensis** (Olsson) Pl. 73, figs. 8-10

1932. *Pseudolatirus tumbeziensis* Olsson, Bull. Amer. Paleont., vol. 19, No. 68, p. 167, pl. 18, figs. 3, 5, 6.

Remarks.—The protoconch of this form is stout and consists of three volutions. The nuclear volutions increase rapidly not only in diameter but in height as well. The last portion of the protoconch carries four to five opisthocyrt axials, the first ones being more oblique.

The protoconch is lacking in the type material of *L. tumbeziensis*, but this shell fits exactly the description of the sculpture of that species. The form from Paraguaná reaches a larger size and shows some variation of the spiral sculpture. The primary spiral sculpture consists of a subsutural spiral and two somewhat carinating spirals on the lower half of the whorl. The spirals, which gradually appear on subsequent whorls, remain weak on a few shells, whereas in the majority they become stronger, so that the relative prominence of the primaries is reduced.

The diameter of the whorls increases somewhat more rapidly in adult stages. Young shells of the material at hand, therefore, resemble the more slender *L. fusiformis* Gabb (1873b, p. 217; Pillsbury, 1922, p. 345, pl. 26, figs. 2, 3) from the Cercado and Gurabo formations of the Dominican Republic. This species is smaller, and has more axials on the body whorl.

Occurrence.—N.V.P. Blue No. 3892, Re 1148, Re 1154, Re 1155, Re 1199.

Subgenus **POLYGONA** Schumacher

Schumacher, 1817, *Essai d'un nouveau système des habitations des vers testacés*, p. 241.

Type species (by monotypy), *Polygona fusiformis* Schumacher (= *Murex infundibulum* Gmelin).

Latirus (Polygona) aff. anapetes Woodring

Pl. 73, fig. 1

1964. *Latirus (Polygona) anapetes* Woodring, U.S. Geol. Sur., Prof. Paper 306-C, p. 274, pl. 47, fig. 12.

Remarks.— There is a single shell, which closely resembles *L. anapetes* from the Chagres sandstone (early Pliocene) of Panamá in general shape and pattern of sculpture. The specimen from Paraguaná is smaller than *L. anapetes*, has only three instead of four primary ribs on the spire whorls, nine instead of seven axials on the body whorl, and the spiral sculpture on the pillar is nearly lacking. Its umbilical opening is smaller, and the inner lip, which carries three instead of four low folds, is not detached from the pillar. All these differences, however, might be caused by the immature stage of the shell from Paraguaná.

The Recent *L. mcgintyi* Pilsbry (1939, p. 84, pl. 5, fig. 8) from Florida is a stouter species with a much thicker pillar. The shell from Paraguaná is separable from *L. infundibulum polius* Woodring (1928, p. 253, pl. 15, figs. 4, 5) (one specimen from Bowden is at hand) by its much shorter siphonal canal. Axial and spiral sculptures of this specimen are less prominent, the fourth columellar fold is lacking, and there are no lamellar growth wrinkles near the suture. The differences to the Recent *L. infundibulum s.str.* are about the same as those indicated by Woodring for the subspecies *L. polius*. As pointed out by Vokes (1938, p. 23) and Rutsch (1942, p. 154) the form from Springvale, Trinidad, is intermediate between the Recent species and *L. polius*. Rutsch mentioned a specimen from Springvale, which has an extremely short siphonal canal, thus approaching the form from Paraguaná.

The general shape of the siphonal canal of this shell rather recalls the Recent *L. brevicaudatus* (Reeve) (Conch. Icon., vol. 4, *Turbinella*, pl. 10, fig. 50, 1847) than *L. infundibulum*.

Occurrence.— N.V.P. Blue No. 3892.

Family **OLIVIDAE**
Genus **OLIVA** Bruguière

Bruguière, 1789, Encyclopédie méthodique, Histoire naturelle des vers, vol. 1, p. XV.

Type species (by monotypy and tautonymy, Lamarck, 1799, Mém. Soc. Hist. Nat. Paris, p. 70), *Voluta oliva* Linné.

Oliva (Oliva) cf. cylindrica G. B. Sowerby I Pl. 73, figs. 5-7

1850. *Oliva cylindrica* G. B. Sowerby I, Quart. Jour. Geol. Soc. London, vol. 6, p. 45.

Shell of medium size. Nuclear whorls moderately high, about two in number. Following whorls straight in profile or slightly concave. Their lower part carries a moderately prominent callus, their upper edge forms a sharp ledge not projecting over the preceding whorl. Spire more or less concave. Columellar folds mostly arranged in pairs, two plicae joining themselves outwards. Adult specimens carry a narrow concave zone on the columella running subparallel to the edge of the parietal callus.

Variability.— Height and concavity of the spire are two variable features often causing confusion in comparing this species with other related forms. The number and arrangement of the parietal plicae also are not constant.

Remarks.— Pflug (1961, pl. 15, figs. 11-13) was the first to give a figure of the lectotype from the Santo Domingan Miocene. If one compares these figures with those of Maury (1917, pl. 10, figs. 14, 14a), it is difficult to decide whether Woodring (1928, p. 228) was right in putting them in the synonymy of *O. plicata* Guppy. In any case the lectotype has a decidedly higher spire than the specimens figured by Pilsbry (1922, pl. 23, figs. 2, 3) which probably represent *O. giraudi* Cossmann (1913, p. 56, pl. 5, figs. 1, 4-8) according to the figures of its lectotype from Martinique given by Pflug (1961, pl. 15, figs. 14, 15).

The close resemblance of several fossil Olivas from the Caribbean region and the fact that their variability is not sufficiently known makes a separation of species not only difficult but arbitrary. Only large suites of topotypes of every "species" would allow a solution of this problem.

Comparisons.— A number of specimens labelled as *O. cercadica* Maury from Bluff 3, Cercado de Mao, Dominican Republic, at

hand agree well with this material. *O. cercadica* is believed to be a synonym of *O. cylindrica* by Woodring (1928, p. 227). *O. cylindrica* resembles *O. reticularis trochala* Woodring (1928, p. 226, pl. 13, figs. 3-5). The topotypes of *O. reticularis trochala* at hand are larger on an average than our specimens. The nuclear whorls of the specimens from Paraguaná are more prominent. Their body whorl forms a slight shoulder, its accentuation depending to some degree on the intensity of concavity of the spire, whereas the Bowden shells are evenly curved. Except in a few specimens the columellar plicae of the Bowden shells are not paired. The specimens described by Rutsch in 1934 as *O. cf. reticularis* Lamarck are larger, stouter, and of heavier appearance. Their spire has about the same height but their parietal folds are never paired. Rutsch's material is believed by Weisbord to be synonymous with his *O. schepmani* (1962, p. 370, pl. 33, figs. 5-13). *O. schepmani* has a more cylindrical nucleus and is not shouldered. *O. cylindrica* is said to have a lower spire and to be stouter than Woodring's material from Bowden and Rutsch's specimens from Punta Gavilán, both authors refer to paratypes. This statement, however, is contradictory to Pflug's figures of the lectotype. A similar species is *O. liodes* Dall (1903, p. 1576 [name only], pl. 58, fig. 1) from the Chipola formation of Florida. According to Dall's figure its shoulder is somewhat more accentuated but otherwise indistinguishable from the material in hand. *O. gatunensis* Toula (1909, p. 702, pl. 25, fig. 12) is not shouldered at all and its spire lower but not concave. The Recent *O. drangai* Schwengel (1951, p. 117, pl. 8, figs. 2, 3) from Tobago is similar to the present form and differs from it only in being more slender and larger.

Occurrence.—N.V.P. Blue No. 3892, Re 1148, Re 1154, Re 1199.

Genus **AGARONIA** Gray

Gray, 1839, The Zoology of Captain Beechey's Voyage, p. 131.

Type species (by monotypy), *Voluta hiattula* Gmelin (quoted from Woodring 1964, p. 281).

Agaronia testacea costaricensis (Olsson) Pl. 73, fig. 11; Pl. 74, figs. 1, 2

1922. *Oliva testacea costaricensis* Olsson, Bull. Amer. Paleont., vol. 9, No. 39, p. 90, pl. 7, figs. 12, 13.

Addenda to original description. — Nuclear whorls about $1\frac{1}{2}$. Sutures narrow but clearly incised. Outer lip moderately thickened, its distance from the main shell axis being greatest in the lower half of the height of the shell.

Syntypes. — Pal. Res. Inst. Ithaca, New York, Nos. 20994, 20995.

Remarks. — The material consists of 10 specimens, the smallest one (H 13748) measuring 17 mm. and the largest one 46.4 mm. in length. They agree well with the figures of the syntypes except that their spire is slightly higher. The band of callus on the lower part of the spire whorls, usually causing a concave whorl profile, is not always prominent. Younger specimens are more slender than adult ones.

Comparisons. — As shown by Keen's figures (1960, p. 423, fig. 630) and those of Abbott (1954, pl. 12, fig. b) the Recent *A. testacea* (Lamarck) has a higher spire than Olsson's original material. In this respect the specimens of this collection are even nearer to the Recent form. The Recent West Coast *A. propatula* (Conrad) (1849, p. 156) is a shorter and stouter species with a lower spire. *A. testacea hadra* Woodring (1964, p. 282, pl. 47, fig. 6) from the lower part of the Gatún formation of the Panamá Canal Zone has a wider aperture and a lower spire. *A. mancinella* (Olsson) (1922, p. 91, pl. 7, figs. 8, 9) from the Gatún formation of Costa Rica is essentially a much more slender (even more slender than *A. testacea*) species with a higher spire. The European *A. plicaria* (Lamarck), of which a rich material from the Burdigalian of the Aquitaine Basin of southern France is at hand, is similar to the shells studied. It is more slender, thus approaching *A. mancinella*, and its band of callus on the lower half of the spire whorls generally strongly accentuated. The siphonal fasciole is strongly set off from the parietal callus, and the callus on the back side near the base of the columella more swollen.

Occurrence. — N.V.P. Blue No. 3892. Re 1199.

Distribution. — Gatún formation, Costa Rica.

Family MITRIDAE

Genus MITRA Röding

Röding, 1798, Museum Boltenianum, p. 135.

Type species (by tautonymy), *Mitra episcopalis* Röding (= *Voluta mitra* Linné).

Subgenus **TIARA** Swainson

Swainson, 1831, Zoological Illustrations, ser. 2, vol. 2, explanation of pl. 50.

Type species (by subsequent designation, Herrmannsen, 1849, *Indicis generum malacozoorum*, vol. 2, p. 576), *Tiara isabella* Swainson. Olsson and Harbison (1953, p. 190) proposed the subgenus *Subcancilla* (type species, *Mitra sulcata* Swainson) to separate a group of species from *Tiara* with heavier sculpture and three instead of five columellar folds. The number of columellar folds is not constant. There are species with strong sculpture and four folds, e.g. *M. dariensis* Brown and Pilsbry, *M. stephensoni* Mansfield or *M. dalli* Engerrand and Urbina (not *M. dalli* Gardner and Aldrich 1919, p. 25, pl. 1, figs. 4, 8). *M. colombiana* Weisbord (= *M. dariensis* according to Woodring, 1964, p. 284) is said to have four and possibly five folds. Thus the distinction of the subgenus *Subcancilla* seems to be unnecessary.

Mitra (Tiara) quirosana F. Hodson

Pl. 73, figs. 12, 13

1931. *Mitra quirosana* F. Hodson, in Hodson and Hodson, Bull. Amer. Paleont., vol. 16, No. 59, p. 42, pl. 20, figs. 3, 4.

Holotype. — Pal. Res. Inst. Ithaca, New York, No. 24105.

Remarks. — This material consists of six specimens. The uppermost of the four spirals on the whorls is less prominent than the others giving a convex appearance to the whorl. The secondary spiral sculpture usually is absent on the material. One shell (H 13751) carries one secondary spiral, which appears suddenly after a rupture of the shell on the penultimate whorl. Another specimen (H 13752) has four spirals on the whorls, the two upper ones being much more accentuated than the others. In addition there is a fifth weak primary spiral just below the suture. *M. quirosana* has a somewhat stout appearance due to the convexity of the whorls and the relatively strong basal constriction.

Comparisons. — *M. dariensis* Brown and Pilsbry (1911, p. 346, pl. 24, fig. 9) from the Gatún formation of the Panamá Canal Zone has somewhat less convex whorls and a more accentuated axial sculpture. The specimens figured by Olsson (1922, pl. 6, fig. 25) and Woodring (1964, pl. 42, fig. 5) have more convex whorls than

those of the original figure, thus approaching *M. quirosana*. If the variability of *M. dariensis* were known, *M. quirosana* might prove to be a synonym of it. *M. illacidata* Woodring (1928, p. 243, pl. 14, fig. 13) from Bowden, Jamaica, has the same sculptural pattern as *M. quirosana* but is smaller and has only three columellar folds. *M. mitrodita* Gardner (1937, p. 408, pl. 48, figs. 10, 11) from the Chipola formation and *M. desmia* Gardner (1937, p. 409, pl. 48, fig. 12) from the Shoal River formation of Florida, both closely resemble *M. quirosana*. In order to establish their differences correctly, however, topotype material should be available. *M. stephensoni* Mansfield (1930, p. 60, pl. 5, fig. 4) from the upper Miocene of Florida has been compared with *M. dariensis*. It is said to be stouter.

Occurrence.—N.V.P. Blue No. 3892, Re 1148, Re 1193.

Distribution.—Hodson's locality No. 6 (Quiroz), State of Zulia, Venezuela (lower Miocene).

Family **TURBINELLIDAE**

Genus **TURBINELLA** Lamarck

Lamarck, 1799, Mém. Soc. Hist. Nat. Paris, vol. 1, p. 73.

Type species (by monotypy), *Voluta pyrum* Linné.

Turbinella falconensis (H. K. Hodson)

Pl. 74, figs. 3-6

1931. *Xancus falconensis* H. K. Hodson, in Hodson and Hodson, Bull. Amer. Paleont., vol. 16, No. 59, p. 40, pl. 22, figs. 1, 3.

Not 1964. *Xancus validus falconensis* H. K. Hodson, Woodring, U.S. Geol. Sur., Prof. Paper 306-C, p. 286, pl. 46, figs. 4-6.

1964. *Turbinella falconensis* (H. K. Hodson), Vokes, Tulane Studies in Geology, vol. 2, No. 2, p. 53.

Shell slender with flat or only slightly convex whorls. There are $2\frac{1}{2}$ smooth nuclear whorls which are equal in diameter giving a turritid appearance. The following whorls (average number: 4) are sculptured by notches elongated in an axial direction which are strongest in their lower part. On the first sculptured whorls there are eight about equally spaced notches, on the following ones six to seven, which consequently are arranged in a line somewhat oblique to the shell axis. The notches are crossed by four primary spiral threads, which rapidly increase in number. The lower ones are stronger corresponding to the strength of the axial notches.

Fine axial growth lines give partly an indistinct reticulate appearance to the sculpture. The suture on the sculptured part of the shell is wavy according to the position of the notches. The sculpture dies out rapidly, so that the adult whorls are nearly smooth. Younger individuals show faint spirals all over their last whorl, especially on its lower part. Growth lines become more and more prominent with increasing age. In gerontic stages they may form conspicuous plicae, especially in front of the suture. Adult whorls only slightly shouldered; their suture clearly channelled. Inner lip moderately broad and only slightly extended upwards. Outer lip not thickened; without internal striae. Columella with three strong folds; anterior-most one weaker than the others. Last whorl constricted in its lower part. Anterior canal straight or slightly curved. Umbilicus indistinct.

Holotype. — Pal. Res. Inst., Ithaca, New York, No. 24111.

Remarks. — The type locality of *T. falconensis* is Cantaure. The material at hand consists of about 60 specimens representing all growth stages. None of these shells exceeds 165 mm.

Comparisons. — *T. dodonaia* (Gardner) (1944, p. 440, pl. 49, fig. 2) from the Oak Grove sand of Florida seems to be the only comparable form. Its apical angle is greater and its whorls regularly convex. The growth lines are prominent already after the axially sculptured whorls, and spiral threads are visible on the adult whorls, two features not present in *T. falconensis*.

Occurrence. — N.V.P. Blue No. 3892, Re 1148, Re 1150, Re 1152, Re 1153, Re 1154, Re 1155, Re 1193, Re 1199.

Distribution. — Miocene of the States of Falcón and Lara, Venezuela.

Family **VOLUTIDAE**

Genus **VOLUTA** Linné

Linné, 1758, Systema Naturae, ed. 10, p. 729.

Type species (by subsequent designation, Montfort, 1810, Conchyliologie systématique, vol. 2, p. 551), *Voluta musica* Linné.

Voluta vautrini, n.sp.

Pl. 74, figs. 7-9

Shell of medium size, heavy. Spire high and pointed. Protoconch high, cylindrical, consisting of about two volutions. Num-

ber of sculptured whorls six. Sculpture starting with axial ridges extending from suture to suture. They number 13 on early whorls, but 10 on the last whorl. After the first three or four whorls the axial ridges become more prominent in their middle part until they form a conspicuous shoulder. They gradually disappear above the shoulder leaving a smooth and somewhat concave area. On the last whorl they gradually weaken towards the base. Body whorl covered by faint growth lines. No spiral sculpture. Five strong plications on the columella and two lirations on the parietal region. Siphonal fasciole moderately prominent.

Holotype.—Basel Natural History Museum, No. H 13755.

Dimensions of holotype.—Height 49.6 mm., greatest diameter 32 mm.

Remarks.—The above description is based on the holotype only. Its outer lip is broken and the siphonal canal not complete. The surface is somewhat worn, so that microscopical sculptural details are not observable.

Comparisons.—*V. vautrini* has affinities to the Recent Caribbean *V. musica* Linné (1758, *Systema Naturae*, ed. 10, p. 733) as well as to *V. alfaroi* Dall (1912, p. 8) from the Miocene of Costa Rica. Its protoconch completely differs from that of *V. musica* (see Pilsbry and Olsson, 1954, pl. 2, fig. 3) but approaches that of *V. alfaroi* (see Pilsbry and Olsson, 1954, pl. 2, fig. 2). In *V. alfaroi* the diameter of the protoconch is larger than that of the first sculptured whorl, whereas in *V. vautrini* the diameter of the whorls gradually increases from the protoconch to the adult stage. Moreover the first sculptured whorl of *V. alfaroi* is considerably lower than that of *V. vautrini*. The general shape and pattern of sculpture of the adult whorls resemble much that of *V. musica*. The number of the axial ridges on the body whorl is the same, but the prominences on the shoulder are even more accentuated in *V. vautrini*. Thus *V. vautrini* represents a form with a protoconch showing affinities to that of *V. alfaroi*, but with an adult stage much like that of *V. musica*.

Occurrence.—Re 1199.

Genus **FALSILYRIA** Pilsbry and Olsson

Pilsbry and Olsson, 1954, *Bull. Amer. Paleont.*, vol. 35, No. 152, p. 21.

Type species (by original designation), *Lyria pycnopleura* Gardner.

Falsilyria spec. ind.

Remarks.—There is a single badly preserved specimen measuring 58 mm. in height (H 13756) which is strongly rolled. The narrow axial ribs of the early whorls, where they number about 11, become broader in later stages. The outer lip and a part of the body whorl are broken. The columella carries five strong folds and two minor ones posterior to them. Siphonal canal broken.

Falsilyria is said to be similar to *Voluta* Linné. The protoconchs of both genera show strongly differing features. Since the protoconch of the specimen is not preserved, its generic assignment to *Falsilyria* is somewhat doubtful.

Comparisons.—The characters, which are preserved on the shell in hand, agree well with those of the type species *F. pycnopleura* (Gardner) (1937, p. 404, pl. 48, figs. 1, 2) from the Chipola formation of Florida. The columellar folds are more prominent on this specimen, and the axial ribs of the body whorl do not reach as far down as in *F. pycnopleura*. The Venezuelan specimen also closely resembles the shell described by Rutsch (1934, p. 87, pl. 7, figs. 7, 8) as *Lyria*, n. sp. aff. *pulchella* (G. B. Sowerby I). The Punta Gavilán specimen has the same number, but more pronounced axial ribs, which are narrower on late whorls. It has more and narrower columellar folds. *Voluta alfaroi* Dall (1912, p. 8; Olsson, 1922, pl. 8, fig. 2) from the Miocene of Costa Rica (see also under *V. vautrini*), of which several well-preserved specimens from Banana River, Costa Rica, are at hand, is somewhat smaller, and has a lower spire. Its columellar folds are much narrower, but the broad axials on the body whorl are of the same type.

Occurrence.—N.V.P. Blue No. 3892.

Family CANCELLARIIDAE

Genus CANCELLARIA Lamarck

Lamarck, 1799, Mém. Soc. Hist. Nat. Paris, p. 71.

Type species (by monotypy), *Voluta reticulata* Linné.

Subgenus CANCELLARIA s.str.

Cancellaria (Cancellaria) epistomifera Guppy

Pl. 75, figs. 1-3

1876. *Cancellaria epistomifera* Guppy, Quart. Jour. Geol. Soc. London, vol. 32, p. 520, pl. 28, fig. 9.
 1913. *Cancellaria epistomifera* Guppy, Cossmann, Jour. Conchyl., vol. 61, p. 53, pl. 4, figs. 5, 6.
 1917. *Cancellaria epistomifera* Guppy, Maury, Bull. Amer. Paleont., vol. 5, No. 29, p. 63, pl. 10, figs. 3, 4, 5.
 1922. *Cancellaria epistomifera* Guppy, Pilsbry, Acad. Nat. Sci. Philadelphia Proc., vol. 73, p. 333, pl. 22, fig. 13.
 1922. *Cancellaria epistomifera* Guppy, Olsson, Bull. Amer. Paleont., vol. 9, No. 39, p. 83.
 Not 1925. *Cancellaria epistomifera* Guppy, Maury, Bull. Amer. Paleont., vol. 10, No. 42, p. 193, pl. 35, fig. 7.
 1961. *Cancellaria (Cancellaria) epistomifera* Guppy, Pflug, Acta Humboldtiana, ser. geol. et pal., Nr. 1, p. 52, pl. 14, figs. 1-9.

Shell of medium size. Spire whorls convex. Postnuclear whorls about six. Protoconch consists of a little more than $2\frac{1}{2}$ volutions. Sculpture starts with a few faint spiral riblets which are crossed by much coarser axials, soon. Spirals and axials become equal in strength on later whorls. There is a tendency to develop varices in later stages (mostly three per whorl). There are five spirals between the sutures. On the penultimate or the body whorl a few secondary spirals may be intercalated. Suture deeply incised. Outer lip crenulated with about a dozen long denticles on its interior surface. Parietal callus thin. Columella with two strong folds, the lower one undulating and having the tendency to double. Siphonal fasciole conspicuous, bordering the narrow umbilicus. Siphonal canal moderately long, bent backwards. Inner margin of siphonal canal accentuated by a more or less conspicuous ridge.

Lectotype.—British Museum (Natural History), No. G 83955.

Remarks.—This material consists of one adult and nine immature shells. Three adult specimens of this species from Zone A (Gurabo formation: middle Miocene), Rio Gurabo, Dominican Republic, are at hand. They have somewhat more inflated body whorls, less conspicuous varices, no secondary spirals on the body whorl, and a slightly thicker parietal callus. The growth lines are more prosocline on the Dominican Republic shells. One of them (H 13758) has an excellently preserved protoconch which is figured here (Pl. 75, fig. 3). It consists of slightly more than $2\frac{1}{2}$ volutions. The sculpture starts with five weak spirals which are crossed by the axials only after a quarter of a volution. Unfortunately the spout-

like eversion of the outer lip, which is typical for *C. epistomifera*, is broken away on our adult shell.

When establishing the new subgenus *Bivetiella*, which is a synonym of *Bivetiella* Wenz (1941, Handbuch der Paläozoologie, Bd. 6, p. 1356), Marks (1949, pp. 456 & 462) mentioned four species belonging to it: *C. epistomifera*, *C. frizzelli*, *C. santiagensis*, and *C. similis*. *C. similis*, the type species (Recent, West Coast of Africa), has widely spaced axials which are by far coarser than the spirals. The same general pattern of ornamentation have *C. frizzelli* and *C. santiagensis*. *C. epistomifera*, however, has a regularly reticulate sculpture except occasional varices. Following Pflug (1961, p. 52), who selected the lectotype, I put *C. epistomifera* in the subgenus *Cancellaria* s. str.

Maury's record of *C. epistomifera* from Springvale, Trinidad, is incorrect. Vokes (1938, p. 20) interpreted it as *C. springvaleensis* Mansfield (= *C. montserratensis* Maury according to Rutsch, 1942, p. 163).

Comparisons. — *C. epistomifera* mainly differs from *C. dariena* Toulou (1909, p. 703, pl. 25, fig. 13; pl. 28, fig. 2) of the Gatún formation of the Panamá Canal Zone, by its more rounded whorls, its lower spire, and its wider aperture. There are three specimens of *C. dariena* from Mt. Hope, Panamá Canal Zone, at hand. The protoconch of one of them (H 13759) is figured here (Pl. 75, fig. 4) for comparison with that of *C. epistomifera*. The number of volutions is the same in both species (about $21\frac{1}{2}$), but they are larger and more inflated in *C. epistomifera*. The sculpture of *C. dariena* starts with prosocline axials and not with spirals as in *C. epistomifera*. These differences, however, correspond to Maury's (1917, p. 63) distinction between form (1) and (2) which is re-discussed by Pflug (1961, p. 52). The two species may be separated by the above mentioned features and the spoutlike eversion of the outer lip in *C. epistomifera*. The present material lies between the two forms and its determination as *C. epistomifera* is perhaps premature until further material is available. *C. bradleyi* Nelson (1870, p. 192, pl. 6, figs. 8, 9) from the Tumbes formation (upper Miocene) of northern Perú is somewhat smaller, has a coarse and more regular reticulate sculpture, and a more accentuated shoulder. *C. defuniak* Gardner (1937, p. 365, pl. 44, figs. 1, 2) from the Shoal

River formation (middle Miocene) of Florida is smaller, has more and closer set spirals, a much stronger upper columellar fold, and only inconspicuous varicose axials. The Recent *C. reticulata* (Linné) and the fossil species, which are probably related to it, as *C. reticulata leonensis* Mansfield (1930, p. 46, pl. 3, fig. 12), *C. barretti* Guppy (1866a, p. 289, pl. 17, fig. 11) and *C. conradiana* Dall (1890, p. 42, pl. 3, fig. 13) are generally larger, have a higher spire, and a more regular reticulate sculpture without varices.

Occurrence.—N.V.P. Blue No. 3892, Re 1155.

Distribution.—Cercado and Gurabo formations (middle Miocene), Dominican Republic. Gatún formation, Panamá Canal Zone.

Cancellaria (Cancellaria ?) lavelana H. K. Hodson Pl. 75, figs. 5, 6

1931. *Cancellaria lavelana* H. K. Hodson, in Hodson and Hodson, Bull. Amer. Paleont., vol. 16, No. 59, p. 44, pl. 24, fig. 12.

Addenda to original description.—Protoconch consists of nearly three strongly inflated volutions, its axis being oblique to the main shell axis. Sculpture starts with a slightly prosocline axial rib which is immediately followed by a few much weaker spirals. There are about five spirals between the sutures which have the same strength as the axials on later whorls. Thickening of single axials is rare. Sutures deeply incised. Posterior end of aperture reaches relatively high. There is a small denticle between the two columellar folds. Inner margin of siphonal canal ridgelike. Siphonal fasciole prominent. Siphonal canal only slightly bent backwards. Umbilicus large.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 24123.

Remarks.—There are only two specimens of this species. The columellar folds are not so wide as those of the holotype, and there are less internal lirae on the outer lip. The parietal callus is thicker than is typical for *Cancellaria s. str.* but not enough to conceal the sculpture of the body whorl entirely.

Comparisons.—This species is similar to *C. guppyi* Gabb (1873b, p. 236) from the Miocene of the Dominican Republic. Its parietal callus, however, is thinner, and there is no ridge extending from the posterior end of the aperture into the aperture. The umbilicus is more closed according to Pilsbry's figure (1922, pl.

22, fig. 7). Gabb mentioned only two nuclear whorls in the original description. *C. laqua* Mansfield (1935, p. 26, pl. 2, fig. 5) from the Arca Zone (upper middle Miocene) of Florida is smaller, has only two nuclear whorls, less post-nuclear whorls, and a thinner parietal callus. *C. pinguis* Gardner (1937, p. 370, pl. 44, figs. 12, 13) from the Shoal River formation (middle Miocene) of Florida is said to have four nuclear volutions. It differs from *C. lavelana* in the same way as *C. laqua*. The comparison of the original materials of these two Floridian species might perhaps prove their identity. *C. emydis* Dall and Ochsner (1928, p. 105, pl. 2, fig. 7) from the Pleistocene of Albemarle Island, Galapagos group, has some resemblance to the present species. It has a less inflated body whorl, more accentuated axial ornamentation, and apparently no ridge at the posterior end of the aperture.

Occurrence. — N.V.P. Blue No. 3892.

Distribution. — Upper middle Miocene, La Vela area, Falcón, Venezuela.

Cancellaria (Cancellaria) aff. rowelli Dall

Pl. 75, figs. 7, 8

1896. *Cancellaria rowelli* Dall, in Guppy and Dall, U.S. Nat. Mus., Proc., vol. 19, p. 307, pl. 29, fig. 1.

Shell small, slender. Protoconch consists of nearly three volutions. Postnuclear whorls five. Sculpture starts with axials. Soon four or five spiral threads appear, the two posteriormost ones being more prominent than the others. The younger spire whorls appear somewhat shouldered by the posteriormost spiral. On later whorls additional spirals are intercalated, the axials become more conspicuous than the spirals and often form varix-like thickenings. Outer lip thickened, carrying (mostly) eight denticles within. Parietal callus thin. Columella with two folds and a ridge bordering the siphonal canal. Between the two folds there is a little denticle. Siphonal fasciole well developed. Umbilicus partly covered by columellar callus. Siphonal canal short, slightly bent backwards.

Variability. — The two posteriormost spirals may form minute spines at the intersections with the axials on early spire whorls. They may remain more prominent even on the body whorl or have the same size as the other spirals. The tendency to form varices is variable. Varices may be predominant on the body whorl or remain nearly absent at all.

Remarks.—There are 21 specimens of this form. They consistently differ in one point from *C. rowelli*: the larger upper columellar fold is not in direct connexion with the siphonal fasciole as shown by the original figure and that given by Olsson (1922, pl. 6, fig. 7). Moreover, the shells remain smaller than *C. rowelli*. The specimen figured by Weisbord (1929, pl. 6, figs. 9, 10) from the middle Miocene of northern Colombia has more axial thickenings than that from the Gatun formation figured by Olsson.

Comparison.—*C. sursalta* Marks (1949, p. 461, pl. 78, fig. 4) from the lower Miocene of southwestern Ecuador is a smaller species and has no tendency to form varices. But it is similar in general form and has also the uppermost spirals more prominent.

Occurrence.—N.V.P. Blue No. 3892.

Subgenus **EUCLIA** H. and A. Adams

H. and A. Adams, 1854, *The Genera of Recent Mollusca*, vol. 1, p. 277.

Type species (by subsequent designation, Cossmann, 1899, *Essais de Paléoconchologie comparée*, vol. 3, p. 10), *Cancellaria cassidiformis* G. B. Sowerby I.

Compare also Olsson's remarks (1932, pp. 157-158).

Cancellaria (Euclia) werenfelsi, n.sp.

Pl. 75, figs. 9-11

Shell of medium size. Protoconch consists of $2\frac{3}{4}$ volutions, its axis being oblique to that of the main shell axis. Postnuclear whorls five. Sculpture starts with prosocline axials. A few faint spiral threads appear after the first or second axial, which gradually increase in number on succeeding whorls. Already on the first sculptured whorl one spiral becomes more prominent than the others and forms a shoulder. At the intersections with the axials there are nodes which develop into pointed prominences in late stages. The area between shoulder and suture is concave just behind these prominences but becomes somewhat convex towards the suture. It carries two to four spirals. Below the shoulder there are about four spirals with occasional secondary threads. The body whorl carries about a dozen spirals below the shoulder with almost as many secondaries. Axials on the body whorl heavy, disappearing towards base, about nine in number. In younger stages their number is much higher. Growth lines slightly prosocline. Thickened

outer lip carries about 10 lirations. Parietal callus thick. Columella with two folds and one, two or three denticles or pustules between them. Upper border of siphonal canal ridgelike. Siphonal canal short, slightly bent backwards. Siphonal fasciole prominent. Umbilicus narrow, partly covered by callus.

Holotype.—Basel Natural History Museum, No. H 13765.

Dimensions of holotype.—Height 26.1 mm., greatest diameter 16.1 mm.

Remarks.—The material consists of the holotype and ten paratypes. Seven paratypes are young individuals. Young shells have a stouter general outline than adult ones. Their outer lip is somewhat angulated at the shoulder, whereas on adult specimens it is rounded.

Paratypes have been sent to the British Museum (Natural History), the Paleontological Research Institution, Ithaca, New York and the U.S. National Museum, Washington, D.C.

Comparisons.—*C. karsteni* Anderson (1929, p. 114, pl. 10, figs 7-9) from the Tubera group (middle Miocene) of northern Colombia, of which there is a cast of a type at hand, mainly differs from this material by its more developed spines, the more concave area above the shoulder, and the closed umbilicus. It has the same number of axials on the body whorl, but more spirals below the shoulder. *C. harrisi* Maury (1917, p. 64, pl. 10, figs. 9, 10) from the Cercado formation (middle Miocene) of the Dominican Republic differs by its more numerous and much narrower axials on the body whorl. Its body whorl seems to be more inflated, and there are no or only minute spines. *C. larkinii* Nelson (1870, p. 192, pl. 6, fig. 7) from the Tumbes formation (upper Miocene) of northern Perú has also more axials on the body whorl, and the spirals are more prominent. *C. venezuelana* H. K. Hodson (in Hodson and Hodson, 1931a, p. 45, pl. 23, figs. 1, 4) from the upper middle Miocene of Falcón, Venezuela, is a larger species, has a more inflated body whorl, more numerous, but less accentuated axials, and a less pronounced shoulder.

Occurrence.—N.V.P. Blue No. 3892.

Subgenus **BIVETIELLA** Wenz

Wenz, 1941, Handbuch der Paläozoologie, Bd. 6, p. 1356. (= *Bivetiella* Marks, 1949, p. 456).

Type species (by original designation), *C. similis* G. B. Sowerby I.

Cancellaria (Bivetiella) beata, n.sp.

Pl. 75, figs. 12-14

Shell of medium to large size, stout. Spire short. Protoconch consists of a little more than three volutions. Postnuclear whorls about five. Sculpture starts with an axial which is immediately followed by four weak spirals. First sculptured whorl with 10 or 11 axials. On succeeding whorls one of the spirals becomes more prominent, forms a rounded shoulder, and carries spines at the intersections with the axials. Posterior to this spiral there are two other spirals with one or two secondaries on later whorls. The first spiral below the shoulder is also coarser and carries minor spines. It is followed anteriorly by about ten spirals, mostly with secondaries in their interspaces. Number of axials on body whorl nine or ten. These are moderately strong and disappear towards the base. Outer lip thickened, its margin crenulated, with numerous lirations within. It is strongly everted just below its middle portion. Parietal callus thin. A more or less pronounced ridge borders a shallow groove at the posterior end of the aperture. Columella with two folds and a few weak pustules between them. Upper part of siphonal canal bordered by a ridge which may become sharp. Siphonal canal short, wide, bent backwards. Siphonal fasciole prominent bordering a narrow umbilicus which may be closed.

Holotype. — Basel Natural History Museum, No. H 13767.

Dimensions of holotype. — Height 38.7 mm., greatest diameter 28 mm.

Remarks. — The material at hand consists of the holotype and six paratypes. One of the paratypes carries *Balanus* on its body whorl.

Paratypes have been sent to the British Museum (Natural History), the Paleontological Research Institution, Ithaca, New York, and the U.S. National Museum, Washington, D.C.

Comparisons. — *C. santiagensis* Marks (1949, p. 462, pl. 78, fig. 6) from the lower Miocene of northern Ecuador has more spirals on early whorls. It is a smaller species, has about the same number of axials per whorl, but a less conspicuous spiral sculpture. *C. frizzelli* Marks (1949, p. 462, pl. 78, fig. 5) from the Daule formation

(middle Miocene) of southern Ecuador is much smaller and differs in details of sculpture. *C. charapota* Olsson (1942, p. 60, pl. 8, fig. 3) from the middle Miocene of the West Coast of Ecuador is a smaller species with similar but less spiny sculpture. It mainly differs by its irregular pustulations on the inner lip.

Occurrence.—N.V.P. Blue No. 3892.

Cancellaria (subgenus ?) **paraguanensis** H. K. Hodson Pl. 75, figs. 15, 16

1931. *Cancellaria paraguanensis* H. K. Hodson, in Hodson and Hodson, Bull. Amer. Paleont., vol. 16, No. 59, p. 44, pl. 24, fig. 10.

Shell of medium size. Spire high. Protoconch not wholly preserved, but probably consists of $2\frac{1}{4}$ volutions with large initial turn. Postnuclear whorls about five. Sculpture starts with an axial which is immediately followed by five primary spirals. The axials become broader with increasing age, the last ones being more rounded, the others somewhat sharpened. The spirals cross the axials without forming nodes. Single secondary spirals already appear on the fourth sculptured whorl and are present in nearly all the interspaces on the body whorl. Outer lip thickened, crenulated, with lirations. Parietal callus thin. Columella with two folds and a ridge bordering the upper part of the siphonal canal. Siphonal fasciole strong, with somewhat erect lamellae, where it is crossed by axial ribs. Umbilicus large. Siphonal canal slightly bent backwards.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 24122.

Remarks.—There are five specimens of this species. None of them shows the denticle between the two strong columellar folds mentioned in the original description. The lirations on the inner surface of the outer lip are not continuous but occur on areas corresponding to large axial ribs on the outer surface.

Comparisons.—It is difficult to find species which might be compared with *C. paraguanensis*. *C. alternata* Conrad (1834, p. 155; Martin, 1904, p. 161, pl. 43, figs. 1-3) from the Miocene of Maryland is smaller, has more inflated whorls, and broader axials.

Occurrence.—N.V.P. Blue No. 3892, Re 1153.

Distribution.—Known from type locality only.

Subgenus **CHARCOLLERIA** Olsson

Olsson, 1942, Bull. Amer. Paleont., vol. 27, No. 106, p. 61.

Type species (by original designation), *Cancellaria perdiciana* Olsson.

Cancellaria (Charcolleria) terryi Olsson

Pl. 75, figs. 17-19

1942. *Cancellaria (Charcolleria) terryi* Olsson, Bull. Amer. Paleont., vol. 27, No. 106, p. 62, pl. 8, fig. 1.

Shell of medium size. Spire high. Postnuclear whorls five to six, strongly rounded. Protoconch consists of about $2\frac{1}{2}$ volutions, its axis being oblique to the main shell axis. Sculpture starts with six fine spiral riblets. After about a quarter of a volution equally spaced axials appear causing more or less pronounced nodes at their intersection with the spirals and forming a reticulate sculpture. The axials become equal in strength as the spirals but are transformed into and replaced by growth lines on late whorls, so that the spiral sculpture is predominant. There are between seven and ten spirals on adult whorls. Body whorl constricted towards base. Outer lip thickened carrying numerous long denticles. Parietal callus moderately thick. Columella with a strong upper and a weaker lower fold which is more oblique than the upper one. Siphonal canal moderately long, somewhat bent backwards. Umbilicus narrow. Siphonal fasciole generally weak.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 4045.

Variability.—The apical angle is not constant. One can distinguish between two extremes: a slender form with moderately convex whorls, and a stouter form with larger apical angle and strongly convex whorls. However, all intermediate stages are represented in the material.

The siphonal fasciole, although weak in general, is more prominently developed on a few specimens. Thus the umbilicus appears more conspicuous. Discontinuous growth of the shell causes irregularly set growth lines and varix-like thickenings. A more or less distinct swelling subparallel to the columellar folds and situated in the continuation of the inner margin of the siphonal canal may be present.

Remarks.—The material consists of 20 specimens, most of which are in a good state of preservation. The holotype of this species is an incomplete shell lacking the protoconch, the siphonal canal, and part of the aperture. Its whorls have the convexity of the present more slender specimens.

Comparisons.—The material is distinguished from *C. perdiciana* Olsson (1942, p. 61, pl. 8, fig. 5) from the lower Miocene of Colombia by its more convex whorls, more incised suture, less prominent umbilicus, and the somewhat stronger sculpture. *C. perdiciana* has less whorls, although it is larger. The present specimens have some resemblance with *C. engonata* Conrad (1842, p. 188) from the Calvert formation of Maryland (see also Martin, 1904, p. 162, pl. 43, fig. 4). *C. engonata* is a smaller species and has a stronger axial sculpture.

Occurrence.—N.V.P. Blue No. 3892, Re 1199.

Distribution.—Charco Azul formation (Pliocene), Panamá.

Genus **TRIGONOSTOMA** Blainville

Blainville, 1827, Manuel de Malacologie et de Conchyliologie, p. 652.

Type species (by tautonymy and monotypy), *Delphinula trigonostoma* Lamarck.

Trigonostoma woodringi, n.sp.

Pl. 76, figs. 1, 2

Shell large. Protoconch not well preserved, probably consists of about two volutions. Postnuclear whorls $4\frac{1}{4}$. Early sculpture consists of six spirals with secondaries on later whorls. Spirals crossed by numerous faint axials causing beads at the intersections. One spiral, situated at about the middle of the whorl, becomes somewhat stronger than the others on later whorls, and carries more prominent beads. Early spire whorls evenly convex, but late ones slightly angulated by the medial spiral. Subsutural channel wide on body whorl, smooth except for numerous close-set prosocline growth lines. The axials become much more prominent than the spirals on the body whorl, where they number 10. The broad and elevated shoulder carries, where crossed by an axial, two nodes, one exteriorly and one towards the suture. Outer lip thickened, crenulated, with 13 long lirae within. Posterior end of aperture with a ridge extending far into the aperture. Parietal callus thick. Inner lip also thick, its callus erect and running obliquely towards the outer lip. Columella with three folds. Siphonal fasciole bordering the wide and deep umbilicus.

Holotype.—Basel Natural History Museum, No. H 13774.

Dimensions of holotype.—Height 28 mm., greatest diameter 22 mm.

Remarks.— This species is represented by the holotype only.

Comparisons.— *T. toroense* (Olsson) (1922, p. 84, pl. 6, fig. 4) from the Gatún formation of Panamá has more rounded whorls, more axials per whorl and, if Toula's figure (1911, pl. 30, fig. 10) represents *T. toroense*, a less oblique inner lip. *T. insulare* (Pilsbry and Johnson) (1917, p. 163; Pilsbry 1922, pl. 22, fig. 11) has more rounded whorls, a shorter spire, and more axial ribs on the body whorl. Pilsbry and Johnson referred to Toula's above mentioned figure as a possible synonym of *T. insulare*. The type of *T. insulare* seems to differ from Toula's specimen by its more oblique inner lip. *T. gurabis* (Maury) (1917, p. 65, pl. 10, fig. 11) from the Guarbo formation of the Dominican Republic is a smaller species, its inner lip is nearly vertical, and it has stronger spiral, but weaker axial sculpture than *T. woodringi*. *T. beatum* Pilsbry and Harbison (1933, p. 108, pl. 3, fig. 1) from the Miocene of New Jersey is similar in general form and sculpture but differs in being smaller and in having a less oblique inner lip.

Occurrence.— N.V.P. Blue No. 3892.

Family MARGINELLIDAE

Genus PRUNUM Herrmannsen

Herrmannsen, 1852, *Indicis generum malcozoorum. Supplementa et corrigenda*, p. 113.

Type species (by original designation), *Voluta prunum* Gmelin.

Subgenus PRUNUM s.str.

Prunum (Prunum) quirosense (F. Hodson)

Pl. 76, figs. 6, 7

1927. *Marginella quirosensis* F. Hodson, in Hodson, Hodson, and Harris, Bull. Amer. Paleont., vol. 13, No. 49, p. 74, pl. 37, figs. 3, 4, 8.

1927. *Marginella quirosensis paraguayensis* F. Hodson, *idem*, p. 75, pl. 37, figs. 1, 2.

Shell solid reaching 20 mm. in height. Nuclear whorls $1\frac{1}{2}$, distinguished on well-preserved specimens from the later whorls, which number 4 to $4\frac{1}{2}$, by their white colour. Spire moderately elevated. Whorls flat or slightly convex, sutures marked by a somewhat incised line which may be obscured by a thin film of callus. Surface of body whorl smooth. Outer lip straight and strongly thickened without denticles on its inner surface. Apical sinus only weakly indicated. Inner lip with four columellar folds on the an-

terior half, the two lower ones being closer set and more obliquely arranged than the upper ones. The anteriormost fold continues into the moderately swollen edge of the siphonal canal and the thickened outer lip. The parietal region carries an elevated ridge of callus nearly parallel to the main shell axis.

Holotype. — Pal. Res. Inst., Ithaca, New York, No. 22864.

Variability. — The height of the spire and its profile are not constant. The whorls may be nearly flat or convex and separated by the feebly incised suture. The callus surrounding the upper end of the aperture may extend more or less towards the apex, but it never covers more than the lowest of the spire whorls. The upper part of the body whorl generally is strongly inflated giving a stout appearance to this species, but more slender specimens are not rare.

Remarks. — This species is represented by about 200 specimens. Their average height lies between 17 and 18 mm. According to Hodson the subspecies *P. paraguayense* differs from *P. quirosense* s.str. by its larger size only. The two holotypes measure 19.0 mm. and 14.4 mm. in height, respectively. The smallest adult individual of the present collection has a height of 14.4 mm. the largest one of 20 mm. Because all intermediate sizes are represented, the subspecies *P. paraguayense* is put in the synonymy of *P. quirosense* s. str. Young specimens are generally more slender. The axial ridge of callus on the parietal region seems to be a constant feature.

Comparisons. — *P. berjadinense* (F. Hodson) (in Hodson, Hodson, and Harris, 1927, p. 75, pl. 37, figs. 11, 13; pl. 40, figs. 16, 18) is less inflated in the upper part of the body whorl. According to Hodson it further differs by a shorter spire and in lacking the axial elevation of callus on the parietal region. *P. incrassatum* (Nelson) (1870, p. 197, pl. 6, figs. 5, 6) which is recorded from the Zorritos formation by Spieker (1922, p. 44) and the Tumbes formation of Perú by Olsson (1932, p. 166), is another stout species. It differs from *P. quirosense* by its lower spire. *P. calypsonis* (Maury) (1925, p. 199, pl. 34, figs. 12, 13), of which many topotypes from Springvale, Trinidad, are at hand, is a slender form. It has a thicker callus on the parietal region which reaches up to the protoconch. *P. apalachee* (Gardner) (1937, p. 395, pl. 47, fig. 5) from the Chipola formation of Florida is somewhat smaller than

P. quirosense, less inflated, and apparently with no axial ridge on the parietal region.

Occurrence.—N.V.P. Blue No. 3892, Re 1148, Re 1154, Re 1155, Re 1193, Re 1199.

Distribution.—Miocene of the States Zulia and Falcón, Venezuela.

Genus **PERSICULA** Schumacher

Schumacher, 1817, *Essai d'un nouveau système des habitations des vers testacés*, p. 235.

Type species (by monotypy), *Persicula variabilis* Schumacher.

Subgenus **RABICEA** Gray

Gray, 1857, *Guide to the systematic distribution of Mollusca in the British Museum*, p. 37.

Type species (by monotypy), *Marginella interrupta* Lamarck.

According to Pilsbry and Lowe (1932, p. 62) and others this type species is synonymous with *Voluta interruptolineata* Megerle von Mühlfeld.

Persicula (Rabicea) venezuelana lavelana (F. Hodson) Pl. 76, figs. 3, 4

1927. *Marginella venezuelana lavelana* F. Hodson, in Hodson, Hodson, and Harris, *Bull. Amer. Paleont.*, vol. 13, No. 49, p. 78, pl. 40, figs. 3, 10, 11.

1927. *Marginella venezuelana falconensis* F. Hodson, *ibid.*, p. 78, pl. 40, figs. 4, 5.

1934. *Persicula (Rabicea) venezuelana lavelana* F. Hodson, Rutsch, *Abh. Schweiz. Pal. Ges.*, Bde. 54-55, p. 91, pl. 6, figs. 9-12.

1962. *Persicula (Rabicea) venezuelana lavelana* (F. Hodson), Weisbord, *Bull. Amer. Paleont.*, vol. 42, No. 193, p. 413, pl. 37, figs. 15, 16; pl. 38, figs. 1-4.

Holotype.—Pal. Res. Inst., Ithaca, New York, No. 22887.

Remarks.—The type material of Hodson's subspecies *P. falconensis* comes from Cantaure, Central Paraguaná. The numerous specimens from the Punta Gavilán formation described by Rutsch (1934, p. 91) as *P. venezuelana lavelana* are larger on an average and also somewhat more inflated. Their anterior sinuses are about equal in intensity, the posterior ones narrower. The number of columellar folds behind the strong pleat may vary in the material from two to five. In general two of them are well developed, and the rest small or even only weakly indicated.

Comparisons.—Rutsch (1934, p. 92) compared this species with *P. propeobesa* (Mansfield) (1925, p. 41, pl. 6, fig. 10) and

several Recent species. *P. hodsoni* Weisbord (1962, p. 412, pl. 38, figs. 5-8) from the Mare and Abisinia formations (Pliocene and Pleistocene) of the Cabo Blanco area differs by its thin outer lip which is not denticulated within, and the many more columellar folds. *P. interrupta marcana* Weisbord (1962, p. 409, pl. 37, figs. 9-14) from the Mare formation of the Cabo Blanco area shows a conspicuous margination of the outer lip, and the posterior edge of the outer lip extends over the top of the spire. Specimens of the Recent *P. interruptolineata* (Megerle) from St. Thomas at hand possess a heavily thickened outer lip with numerous denticles. There are more columellar folds, and the outer lip reaches higher up than the spire. The Recent *P. adamsiana* Pilsbry and Lowe (1932, p. 62, pl. 4, fig. 9) from the Pacific Coast of Panamá is more slender, has a narrower posterior canal, and the outer lip is thinner, with denticles on its lower half only.

Occurrence. — N.V.P. Blue No. 3892, Re 1155.

Distribution. — Middle Miocene to Pleistocene of Venezuela (see also Weisbord 1962, p. 415).

Family TURRIDAE

Genus POLYSTIRA Woodring

Woodring, 1928, Carnegie Inst. Wash., Pub. 385, p. 145.

Type species (by original designation), *Pleurotoma albida* Perry.

Polystira barretti (Guppy)

Pl. 76, figs. 5, 16

1866. *Pleurotoma barretti* Guppy, Quart. Jour. Geol. Soc. London, vol. 22, p. 290, pl. 17, fig. 6.

1928. *Polystira barretti* (Guppy), Woodring, Carnegie Inst., Wash., Pub. 385, p. 146, pl. 4, figs. 6, 7.

? 1950. *Polystira albida* (Perry), Alencaster-Ibarra, Bol. Asoc. Mexicana Geol. Petrol., vol. 2, No. 9, p. 564, fig. 8.

? 1953. *Polystira albida* (Perry), Fargo, in Olsson and Harbison, Acad. Nat. Sci. Philadelphia, Mon. 8, p. 368, pl. 24, fig. 2.

? 1960. *Turris albida virgo* Lamarck, Barrios, Bol. Geol., vol. 6, Nos. 1-3, Informe No. 1082, p. 293, pl. 12, fig. 1.

Not 1960. *Polystira barretti* (Guppy), Perrilliat Montoya, Paleont. Mex., No. 8, p. 30, pl. 4, figs. 13, 14.

1961. *Polystira barretti* (Guppy), Pflug, Acta Humboldtiana, ser. geol. et pal., Nr. 1, p. 70, pl. 20, figs. 1, 4. For additional citations see this publication.

Holotype. — British Museum (Natural History), No. 64065.

Remarks. — The stratigraphically, as well as geographically,

wide-spread group of *P. albida* (Perry), (1811, pl. 32, fig. 4) still is an unsolved problem. While Woodring (1928, p. 146) pointed out some differences between *P. albida* and *P. barretti* Rutsch (1934, pp. 98-99) tended to unite both species. It is useless, however, to give comparative remarks, unless they are based on a large material from many localities and stratigraphic horizons. The variability of the size of the shell and of the strength of the spiral keels have been the cause for the proposition of several names. If one considers the fact that even in a single population the strength of the spiral keels may vary considerably, it becomes evident that only after a careful study of this group will it be possible to apply these names correctly.

The material from Paraguaná corresponds well with the figures of the holotype of *P. barretti* given by Pflug (1961, pl. 20, figs. 1, 4), but none of the present numerous specimens reaches the size of the holotype.

Occurrence. — N.V.P. Blue No. 3892, Re 1148, Re 1154, Re 1199.

Distribution. — Miocene, Jamaica (type locality).

Genus **CRASSISPIRA** Swainson

Swainson, 1840, Treatise on Malacology, p. 313.

Type species (by subsequent designation, Herrmannsen, 1847, *Indicis generum malacozoorum primordia*, vol. 1, p. 318), *Pleurotoma bottae* Valenciennes.

Crassispira henekeni (G. B. Sowerby I)

Pl. 76, figs. 17, 18

1850. *Pleurotoma henikeri* G. B. Sowerby I, Quart. Jour. Geol. Soc. London, vol. 6, p. 50, pl. 10, fig. 6.

1917. *Drillia henekeni* (Sowerby), Maury, Bull. Amer. Paleont., vol. 5, No. 29, p. 53, pl. 8, figs. 17, 18.

1922. *Drillia henekeni* (Sowerby), Pilsbry, Acad. Nat. Sci. Philadelphia, Proc., vol. 73, p. 318, pl. 17, fig. 3.

? 1925. *Drillia henekeni* (Sowerby), Maury, Bull. Amer. Paleont., vol. 10, No. 42, p. 188, pl. 32, fig. 13.

? 1960. *Drillia henekeni* (Sowerby), Barrios, Bol. Geol., vol. 6, Nos. 1-3, Informe No. 1082, p. 293, pl. 11, fig. 10.

Shell of medium to large size. Protoconch consists of about three smooth, high volutions. Sculpture starts with opisthocline, relatively broad axials, numbering eight (sometimes nine) per whorl on the whole shell. A weak subsutural spiral already appears on the first sculptured whorl becoming more prominent subsequently. On later whorls the axials are more and more restricted to the lower

two-thirds of the volution leaving a concave and generally unsculptured area below the subsutural spiral. There is a conspicuous shoulder in later stages. Below the shoulder there are five spirals. The spirals on the body whorl generally are interrupted by the growth lines, especially on large specimens. Anal sinus moderately deep, lying below the subsutural spiral. Aperture not constricted towards base. Siphonal sinus only weakly indicated. Siphonal fasciole not conspicuous. Parietal callus heavy. Inner lip may be detached from pillar in large specimens.

Type. — British Museum (Natural History).

Remarks. — The present material consists of 22 specimens. Most of them are immature. The largest shell (apex broken) (H 13781) reaches a height of 52 mm. The shoulder of the type specimen as figured by Sowerby is less accentuated than in our material. This may be a reason to name the material at hand subspecifically, but since there are also specimens with a similar prominence of the axials and the shoulder as in the type, this feature is considered to fall within the variability of *C. henekeni*.

The anal fasciole is generally smooth in this species, but there are a few shells which carry three to four faint spirals on the anal fasciole.

Comparisons. — *C. henekeni caroniana* (Maury) (1925, p. 189, pl. 32, fig. 12) from Springvale, Trinidad, of which several topotypes are at hand, is larger, and has more numerous, but less prominent axial ribs. The anal fasciole is somewhat broader and the subsutural spiral more developed. Specimens of *C. henekeni caroniana* from the upper Miocene of Cubagua at hand are larger and heavier than those from Springvale. *C. aegis* Woodring (1928, p. 151, pl. 4, fig. 12) from Bowden, Jamaica, is extremely similar to *C. henekeni caroniana*. The lack of topotype material of *C. aegis* does not allow comparative remarks. The type species of *Crassispira*, the Recent *C. bottae* (Valenciennes), as figured by Fargo (in Olsson and Harbison 1953, pl. 16, fig. 4), has the same type of sculpture as the above mentioned species, but the axials are strongly reduced; the shell is somewhat less slender, and the aperture shorter. Woodring (1928, p. 152) suggested the introduction of a new supra-specific name. The Recent *Drillia inaequistriata*

Li (1930, p. 275, pl. 8, fig. 71; Pilsbry, 1931, pp. 434, 437, pl. 41, fig. 2) from Panamá Bay shows some general affinities to *C. henekeni*, but is more slender, and has more axial ribs. Apparently related to this species is the large Recent *C. perla* Smith (1947, p. 53, pl. 2, fig. 1) from the Pearl Islands, Panamá. The original figure of *C. perla* is not sufficient to recognize details.

Occurrence. — N.V.P. Blue No. 3892, Re 1148.

Distribution. — Cercado and Gurabo formations, Dominican Republic. Other occurrences (Trinidad, Colombia) should be confirmed.

***Crassispira conica*, n.sp.**

Pl. 76, figs. 8-11

Shell of medium size, with about eight spire whorls. Protoconch consists of $2\frac{1}{2}$ strongly inflated volutions. First sculpture of numerous faint opisthocyrt axials. The axials number 12 on the second spire whorl and seven on the penultimate whorl. A subsutural spiral appears on the early spire whorls which becomes more or less distinctly doubled in adult stages. The axials are shouldered at about the middle of the volution. There are four to five conspicuous spirals below, and four to five less prominent spirals above the shoulder. Anal sinus moderately deep. Aperture not constricted below. Siphonal fasciole more or less swollen. Umbilical opening sometimes present. Parietal callus relatively thick.

Holotype. — Basel Natural History Museum, No. H 13783.

Dimensions of holotype. — Height 39.5 mm., greatest diameter 13.7 mm.

Remarks. — The material consists of the holotype and 14 paratypes. In a few specimens the apical angle becomes somewhat smaller after the fourth or fifth spire whorl. Otherwise the morphological features are constant.

Paratypes have been sent to the British Museum (Natural History), the Paleontological Research Institution, Ithaca, New York, and the U. S. National Museum, Washington, D. C.

Comparisons. — *C. conica* shows some affinities to *C. henekeni* but is clearly separated from it by its smaller size and its stouter shape. The protoconch of *C. henekeni* is more slender and does not show the closely spaced opisthocyrt axials. Moreover, the anal fasciole of *C. conica* is broader and always sculptured by a few

spirals, whereas that of *C. henekeni* remains smooth. *C. boadicea* (Dall) (1900, p. 1197, pl. 41, fig. 4) from the Oak Grove sand of Florida is similar in general shape but smaller. It has more axials per whorl and tends to have a wider anal fasciole which is weakly sculptured only.

Occurrence.—N.V.P. Blue No. 3892.

Crassispira aff. consors (G. B. Sowerby I)

Pl. 76, figs. 14, 15

1850. *Pleurotoma consors* G. B. Sowerby I, Quart. Jour. Geol. Soc. London, vol. 6, p. 50.

Remarks.—There is a large number of forms which have been attributed to *C. consors*, but there are also many species which have been compared with *C. consors*. Some of these "species" have been treated as synonyms of *C. consors* (see Olsson, 1922, p. 62; Rutsch, 1934, p. 100). The lectotype of *C. consors* has been figured by Pflug (1961, pl. 19, figs. 4, 10). This material (five specimens) is smaller, the anal fasciole is somewhat more concave and the subsutural spiral more strongly developed. Palmer (1923, pl. 2, fig. 8) figured a small specimen of *C. consors* from the Dominican Republic, which may be conspecific with this material. Specimens of *C. alesidota magna* Böse (1906, p. 47, pl. 5, figs. 30, 31, 33, 45) from the Isthmus of Tehuantepec at hand differ from the present material by their larger size only. Those figured by Perrilliat Montoya (1960, pl. 4, figs. 9, 10) have the dimensions of the material from Paraguaná and seem to be identical with it.

It is useless to give comparisons unless a revision of the *C. consors*-group under careful consideration of all the type specimens is made. The following five species are also considered to belong to the *C. consors*-group: *C. calligona* (Maury) (1910, p. 7, pl. 2, fig. 1), *C. paraconsors* Gardner (1937, p. 299, pl. 39, fig. 3), both from the Chipola formation of Florida and *C. calligonoides* Gardner (1937, p. 300, pl. 39, figs. 4, 9) from the Shoal River formation of Florida. These three species have, on adult whorls, the axial sculpture more accentuated than the spiral sculpture, whereas in the lectotype of *C. consors* both elements are of equal strength. In *C. laurentii* Gardner (1947, p. 634, pl. 55, fig. 24) and *C. blountensis* Mansfield (1935, p. 22, pl. 1, fig. 11) these elements are also of equal strength. Their variable strength apparently is generally

considered to fall within the variability of *C. consors* as demonstrated by the numerous published figures of so-called *C. consors*.

Occurrence. — N.V.P. Blue No. 3892.

Genus **CLATHRODRILLIA** Dall

Dall, 1918, U.S. Nat. Mus., Proc., vol. 54, pp. 317, 323.

Type species (by original designation), *Murex gibbosus* Born (= *Pleurotoma gibbosa* Reeve = *Pleurotoma gibbosa* Kiener).

Clathrodrillia puertocolombiana (Weisbord) Pl. 76, figs. 12, 13, 19

1929. *Drillia puertocolombiana* Weisbord, Bull. Amer. Paleont., vol. 14, No. 54, p. 55, pl. 5, fig. 16.

Shell of medium size. Protoconch consists of $2\frac{1}{2}$ closely coiled volutions. First sculpture consists of about 10 slightly opisthocline axials which are broader in their lower part. Suture inconspicuous on the earliest whorls. The spiral sculpture (eight spirals, which are restricted to the interspaces between the axials) appear on the fourth or fifth whorl only. At the same time the upper part of the whorls becomes constricted and forms a prominent, concave anal fasciole. The axials gradually become less conspicuous on the anal fasciole, until they are nearly missing on the body whorl. Adult whorls strongly shouldered. There are four to five prominent spirals below the shoulder which may form small nodules at the intersection points with the axials. The spirals above the shoulder also number four to five, but are much less prominent. The subsutural band is broad, and the growth lines, which are crossing it, are especially well visible. The axials number 18-20 on the penultimate, the spirals about 20 on the body whorl. Nearly a quarter of a volution behind the moderately deep anal sinus there is a strong varix. Axial sculpture missing between this varix and the outer lip. Base of body whorl somewhat constricted. Siphonal notch moderately deep. Siphonal fasciole inconspicuous. Parietal callus heavy, greatly thickened at upper edge of anal sinus. Inner lip detached from pillar.

Holotype. — Pal. Res. Inst., Ithaca, New York, No. 22941.

Remarks. — There are 28 partly young or badly preserved specimens of this species. The various sculptural elements are astonishingly constant. The number of axials on late whorls is lower as indicated in the original description. The probable thin edge of the outer lip is not completely preserved in any of the shells at hand.

Comparisons.—*C. puertocolombiana* is closely related to the Recent *C. gibbosa* (Born) (1778, Index Rerum Nat. Mus. Caes. Vind., pt. 1, Testacea, p. 325). Fargo (*in* Olsson and Harbison 1953, pl. 16, figs. 1, 1a) figured a specimen from the Coast of Cumaná, and Weisbord (1962, p. 435, pl. 41, figs. 13-15) reported this species from the Mare formation (Pliocene) of the Cabo Blanco area. There are a few perfect shells from the "Cabo Blanco beds" of the Cumaná area at hand. They differ from the Paraguaná material only by their heavier appearance, somewhat larger size, and the absence of any spiral sculpture on the anal fasciole of the later whorls. Specimens from the "Miocene" of the Urumaco area at hand are heavier than those from Paraguaná, and thus practically identical with *C. gibbosa* except the spirals on the anal fasciole and their somewhat lower whorls. *C. venusta* (G. B. Sowerby I) (1850, p. 50, pl. 10, fig. 7) from the Gurabo formation of the Dominican Republic, the lectotype of which has been figured by Pflug (1961, pl. 19, fig. 9), mainly differs by its less shouldered whorls. The axial ribs—although reduced—are still well recognizable on the anal fasciole of *C. venusta*; in *C. puertocolombiana* they are feebly developed on the lower part, whereas in *C. gibbosa* they usually are completely lacking on the anal fasciole. *C. subgibbosa* (Pilsbry and Johnson) (1917, p. 153; Pilsbry 1922, pl. 16, fig. 14) from the Dominican Republic has less axials and spirals on adult whorls. The axials persist to the posterior suture.

Occurrence.—N.V.P. Blue No. 3892, Re 1148, Re 1154, Re 1199.

Distribution.—"Miocene" of the Dept. of Atlantico, Colombia.

Clathrodrillia ? n.sp. aff. *C. islalindae* (Maury)

Pl. 77, figs. 15, 16

Shell of medium size, with ten whorls. Protoconch not preserved. Axials seven per volution on early whorls, 14 on penultimate whorl. Axials strongly reduced on anal fasciole. There is a strong varix a quarter of a volution behind the outer lip. Shoulder not prominent. Spiral sculpture consists of five widely spaced grooves below the shoulder and about five much weaker and closer set grooves above. Body whorl with 18 spiral grooves. Anal sinus deep. Notch at base of outer lip well defined. Siphonal canal slightly recurved. Siphonal fasciole not prominent.

Remarks.—There is but a single shell which resembles "*Drillia*" *islandiae* Maury (1917, p. 57, pl. 9, fig. 7) from the Cercado and Gurabo formations of the Dominican Republic. This specimen, twice as high as the Dominican shell, has somewhat more strongly shouldered whorls, and lacks the subcancellate sculpture between the varix and the outer lip. The spiral grooves cross the axial ribs, whereas in *Drillia islandiae* they are restricted to the interspaces.

Occurrence.—N.V.P. Blue No. 3892.

Genus **FUSITURRICULA** Woodring

Woodring, 1928, Carnegie Inst. Wash., Pub. 385, p. 165.

Type species (by original designation), *Turris* (*Surcula*) *fusinella* Dall.

Fusiturricula cf. **jaquensis** (G. B. Sowerby I)

Pl. 77, fig. 5

1850. *Pleurotoma jaquensis* G. B. Sowerby I, Quart. Jour. Geol. Soc. London, vol. 6, p. 51.

Remarks.—"Pleurotoma" *jaquensis* has been redescribed and refigured by Maury (1917, p. 48, pl. 8, fig. 1) and Pilsbry (1922, p. 317, pl. 22, figs. 21, 22). Woodring (1928, p. 167) assigned it to *Knefastia*.

This material consists of a few, partly immature, and not well-preserved specimens. There are nine swollen axial ribs on the last volution of the largest specimen. The whorls of the spire carry six spirals below the anal fasciole, sometimes with a secondary spiral thread in the interspaces. The subsutural thread is more or less strongly developed. *F. jaquensis* has a concave, but smooth (except growth lines) anal fasciole, whereas that of the specimens from Paraguaná carries two or three weak spiral threads.

F. paraservata Gardner (1937, p. 291, pl. 38, figs. 30, 31) from the Chipola formation of Florida is similar in general aspect, but is smaller, and has a less concave anal fasciole. However, if the holotype of *F. paraservata* is an immature specimen, it closely resembles the younger stages of *F. jaquensis*.

Occurrence.—N.V.P. Blue No. 3892, Re 1148, Re 1193.

Genus **KNEFASTIA** Dall

Dall, 1919, U.S. Nat. Mus., Proc., vol. 56, p. 3.

Type species (by original designation), *Pleurotoma olivacea* G. B. Sowerby I.

Knefastia aff. **lavinoides** (Olsson)

Pl. 77, figs. 4, 6, 7

1922. *Turricula lavinoides* Olsson, Bull. Amer. Paleont., vol. 9, No. 39, p. 55, pl. 4, fig. 6.

Remarks.—There are numerous specimens of a form which agrees well in general outline with *K. lavinoides*. While the axial swellings are more or less constant in strength, the prominence of the spiral threads is variable. The most frequent arrangement is that seen in *Turricula* (*Surcula*) *lavinia* Dall (1919, p. 4, pl. 1, fig. 6); the most inflated part of the whorl is ornamented by two spirals with one secondary spiral in early stages and two to three in later stages in their interspace. The lower spiral usually becomes thickened on the axial swellings especially on early whorls. The area below the two spirals carries several other spirals of different strength. The area above the two spirals is concave and sculptured by numerous fine spiral threads. In other specimens the two peripheral spirals are less accentuated, at least on later whorls. Thus the sculpture has a more uniform aspect.

The most striking difference between *K. lavinoides* and the present form is shown by the protoconch. A protoconch of *K. lavinoides* from Hill 1, Banana River, Costa Rica, (Gatún formation) (H 13795) and one from locality 3892 are figured for comparison (Pl. 77, figs. 7, 8). The Costa Rican protoconch is considerably more inflated and has a greater diameter. In addition the apical angle of the Costa Rican shell is somewhat larger.

The concave area below the suture is practically smooth on the shells from Costa Rica, whereas on those from Paraguaná it carries fine spirals.

Comparisons.—*K. (?) sanctidavidis* (Maury) (1925, p. 188, pl. 32, figs. 6, 7) from Manzanilla, Trinidad, (topotypes are at hand) has the same sculptural pattern, but a somewhat more inflated protoconch, and much less developed axial swellings. It is smaller than the form from Paraguaná. *K. glypta* Gardner (1937, p. 293, pl. 38, fig. 34) from the Chipola formation of Florida has the same type of ornamentation. But according to the original figure it is smaller, and its whorls are less inflated.

Occurrence.—N.V.P. Blue No. 3892, Re 1155, Re 1193, Re 1199.

***Knefastia kugleri*, n.sp.**

Pl. 77, figs. 1-3

Shell of medium size. Protoconch missing. First whorls sculptured by axial swellings which are best developed on the middle portion of the shell. They do not extend from suture to suture. First spiral sculpture consists of a median spiral which is thickened on the axial swellings, and a subsutural thread. On subsequent whorls secondary and tertiary spirals are intercalated. Anal fasciole concave. The axial swellings become less prominent on later whorls until they disappear on the body whorl. Anal sinus deep. Outer lip thin, with lirations on its inner surface. Callus on parietal region thin. Siphonal canal moderately long, slightly bent to the left on its lower part. Umbilical opening sometimes indicated.

Holotype.—Basel Natural History Museum, No. H 13796.

Dimensions of holotype.—Height 46.6 mm., greatest diameter 20 mm.

Remarks.—The type material consists of about 60 specimens. The variability of this species is not great. In some specimens the axial swellings are missing on the last few whorls, whereas on others they disappear only on the last or penultimate whorl. Typically the body whorl is strongly inflated and greatly constricted towards the siphonal canal. In some specimens this inflation is less developed, and the shell has a more slender aspect.

Paratypes have been sent to the British Museum (Natural History), the Paleontological Research Institution, Ithaca, New York, and the U. S. National Museum, Washington, D. C.

Comparisons.—The development of the last whorls of *K. kugleri* with their well-separated anal fasciole and the loss of the axial sculpture is unique. No species with similar features has been found. The young stages, however, resemble much that of *K. (?) sanctidavidis* (Maury) (1925, p. 188, pl. 32, figs. 6, 7) from Manzanilla, Trinidad, but *K. kugleri* is larger and has a greater apical angle. *K. lavinoides* (Olsson) (1922, p. 55, pl. 4, fig. 6) from the Gatún formation of Costa Rica has also a similar young stage but retains the axial swellings down to the body whorl. *K. (?) cruziana* (Olsson) (1932, p. 150, pl. 15, figs. 6, 10) from the Zorritos formation of Perú has a much less wavy peripheral spiral and less inflated

whorls, but its sculptural pattern is the same as in *K. kugleri*.

Occurrence.—N.V.P. Blue No. 3892, Re 1148, Re 1152, Re 1155, Re 1199.

Genus **GLYPHOSTOMA** Gabb

Gabb, 1873, Acad. Nat. Sci. Philadelphia, Proc. for 1872, vol. 24, p. 270.

Type species (by monotypy), *Glyphostoma dentiferum* Gabb.

Glyphostoma dentiferum Gabb

Pl. 77, figs. 9, 10

1873. *Glyphostoma dentifera* Gabb, Acad. Nat. Sci., Philadelphia, Proc. for 1872, vol. 24, p. 271, pl. 11, fig. 4.

1873. *Glyphostoma dentifera* Gabb, Amer. Philos. Soc., Trans., vol. 15, new ser. p. 210.

1913. *Clathurella (Glyphostoma) dentifera* (Hinds), Cossmann, Jour. Conchyl., vol. 61, p. 31, pl. 2, figs. 15-17.

1917. *Glyphostoma dentifera* Gabb, Maury, Bull. Amer. Paleont., vol. 5, No. 29, p. 61, pl. 9, fig. 16.

1922. *Glyphostoma dentiferum* (Gabb), Pilsbry, Acad. Nat. Sci. Philadelphia, Proc., vol. 73, p. 324, pl. 17, fig. 15. (January 4).

1922. *Glyphostoma dentifera* Gabb, Olsson, Bull. Amer. Paleont., vol. 9, No. 39, p. 76. (April 21).

Type.—Acad. Nat. Sci., Philadelphia, Pa.

Remarks.—There are seven specimens of this species. No protoconch is preserved. The variability of the height of the spire has already been pointed out by several authors and is also shown by the material from Paraguaná. The number of axials is also variable. On some shells the reticulate sculpture of the body whorl starts on the penultimate whorl, whereas on others the broad axials (mostly numbering 9-11) are still well developed on the penultimate whorl.

Comparisons.—Most species of *Glyphostoma*, which have been described from the West Indian region, are much smaller than *G. dentiferum*. *G. exopitatum* Woodring (1928, p. 192, pl. 8, figs. 7, 8) from Bowden, Jamaica, is smaller, more slender, and is but inconspicuously shouldered. *G. macneili* Mansfield (1935, p. 25, pl. 2, fig. 3) from the *Arca* Zone (upper middle Miocene) of Florida has about the same height as the Paraguaná shells, but is more slender, and has about 30 denticles on the columella, whereas in *G. dentiferum* there are only 13 or 14. *G. harrisi* Maury (1910, p. 14, pl. 3, fig. 10) from the Chipola formation of Florida is a similar species, but has a somewhat stouter spire, a shorter siphonal canal, and seems to lack the reticulate sculpture on the body whorl. Marks (1951, p. 136, pl. 9, fig. 8) figured an unnamed specimen of *Gly-*

phostoma from the Daule formation (middle Miocene) of Ecuador. According to his figure this specimen is separated from the present material mainly by its broad and closely set axial ribs and the rounded whorls.

Occurrence. — N.V.P. Blue No. 3892.

Distribution. — Miocene of the Dominican Republic. Gatún formation of Costa Rica.

Genus **BORSONIA** Bellardi

Bellardi, 1839, Soc. Géol. France, Bull., ser. 1, vol. 10, p. 30.

Type species (by monotypy), *Borsonia prima* Bellardi.

Subgenus **PARABORSONIA** Pilsbry

Pilsbry, 1922, Acad. Nat. Sci. Philadelphia, Proc., vol. 73, p. 326.

Type species (by original designation), *Mitra varicosa*, G. B Sowerby I.

***Borsonia* (*Paraborsonia*) *cantaurana*, n.sp.**

Pl. 77, figs. 11-14

Shell large for the subgenus. Spire high. Protoconch and early sculptured whorls missing. Earliest preserved sculpture consists of an anterior doubled spiral cord (anal fasciole) and a subsutural spiral which are crossed by opisthocyrt growth lines producing nodes at the intersection points. Nodes of the anterior doubled cord connected. Area between the cords concave, with one secondary on young whorls, but with two secondary and also tertiary spirals in adult stages. On early whorls the suture lies just in front of the anal fasciole, but on adult whorls there is an area between them which is sculptured by a few secondary and tertiary spiral threads. With increasing age the subsutural cord becomes divided and less prominent. Sculpture on body whorl consists of weakly noded spirals of alternating size. Inner surface of outer lip with sharp lirations. Columella with two prominent folds, the upper one being larger. Callus of inner lip thin. Siphonal fasciole rounded, without a bordering ridge. Umbilical opening sometimes present.

Holotype. — Basel Natural History Museum, No. H 13805.

Dimensions of holotype. — Height 30.0 mm., greatest diameter 12.0 mm.

Remarks. — The material, which consists of the holotype and 23 paratypes, is somewhat unsatisfactory as type material, since there

are no protoconchs and first sculptured whorls preserved. In addition most paratypes are not in a good state of preservation, so that remarks concerning the variability must be omitted.

B. cantaurana is the fourth described species of *Paraborsonia* from the Caribbean region and is separated from all the others by its larger size.

Paratypes have been sent to the British Museum (Natural History), the Paleontological Research Institution, Ithaca, New York, and the U. S. National Museum, Washington, D. C.

Comparisons.—*B. cantaurana* is certainly most closely related to *B. varicosa* (G. B. Sowerby I) (1850, p. 46) from the Miocene of the Dominican Republic. Sowerby based his species on a single fragment, but Pilsbry (1922, p. 325, pl. 17, figs. 19-21) and Maury (1917, p. 51, pl. 8, fig. 9) gave good figures. Both species have practically the same sculpture, but *B. cantaurana* constantly differs by its smaller apical angle, the higher spire, and the fact that there is no third columellar fold in young shells as indicated by Pilsbry. Large series of *B. varicosa*, however, might show that the above mentioned differences fall within the variability of *B. varicosa*. *B. brassoensis* Mansfield (1925, p. 30, pl. 5, fig. 8) from the Miocene of Trinidad is a much smaller and stouter species. Young specimens from the Brasso-Tabaquite Road at hand also show a third columellar fold like *B. varicosa*. *B. cocoensis* Olsson (1922, p. 78, pl. 5, figs. 23, 24) from the Gatún formation of Costa Rica resembles much more *B. brassoensis* than *B. cantaurana*. It is also a small and stout form but has the area above the anterior doubled spiral slightly concave like *B. cantaurana*.

Occurrence.—N.V.P. Blue No. 3892, Re 1193, Re 1199.

Family CONIDAE

Genus CONUS Linné

Linné, 1758, Systema Naturae, ed. 10, p. 712.

Type species (by subsequent designation, Children, 1823). *Conus marmoreus* Linné.

Although Keen (1960, pp. 479-488) gave a subgeneric system of *Conus s. l.*, which is partly based on Hanna and Strong (1949), such a system is avoided here, because the reliability of subgeneric criteria, as stated by Clench (1942, p. 36), is still too uncertain.

Conus wiedenmayeri, n.sp.

P. 77, figs. 17-19

Shell of small to medium size. Spire low, concave in its young stages, straight later on. The single spire whorls slightly concave. Postnuclear whorls a little more than ten. Only two volutions of the protoconch are preserved which are somewhat oblique to the main shell axis. The sculpture starts with a relatively broad keel on the lower part of the whorl which is ornamented with beads. Posterior to it there is a spiral cord. On succeeding whorls other spirals are intercalated up to a maximum of four. The beads are somewhat less conspicuous on later whorls, set at larger intervals, and they cause a regularly undulating outline of the shoulder, when viewed from the apex. On the last whorl their number is 11. Thus the suture, which is sharply incised, is undulating also. The growth lines of the spire whorls are but weakly curved and inconspicuous compared with the spirals. Anal notch deep. Margin of outer lip thin. At the posterior end of the parietal region there is an oblique groove within the aperture. Aperture wider anteriorly. Body whorl nearly straight in profile, somewhat concave near the base. Growth lines shallowly prosocyr. Spiral sculpture of body whorl restricted to basal part, consists of about a dozen narrow ribs, widely spaced posteriorly, much closer set towards the base. Siphonal fasciole not conspicuous. Upper part of body whorl smooth but with some still recognizable spiral colour markings.

Holotype. — Basel Natural History Museum, No. H 13811.

Dimensions of holotype. — Height 32.8 mm., greatest diameter 18.3 mm.

Remarks. — The material consists of the holotype and one paratype. The oblique groove on the posterior parietal region is well visible on the paratype, because the margin of its outer lip is broken.

C. wiedenmayeri belongs to the subgenus *Conus s. str.* according to Keen's system. The description of *Conus s. str.* given by Woodring (1928, pp. 201-202) agrees nearly perfectly with the characteristics of the two shells at hand.

Comparisons. — No Caribbean species of *Conus s. str.* has been found to be comparable with *C. wiedenmayeri* except perhaps the Recent *C. mus* Hwass. But this species has a less concave spire, a more rounded body whorl, and a spiral sculpture covering the whole

body whorl. There are, however, a few Recent West American forms, which are similar to *C. wiedenmayeri* in general outline, such as young individuals of *C. brunneus* Wood, *C. gladiator* Broderip (1833, p. 55), *C. princeps apogrammatus* Dall (1910, p. 224) and *C. bartschi* Hanna and Strong (1949, p. 271, pl. 5, fig. 5).

Occurrence. — N.V.P. Blue No. 3892.

Conus aff. *molis* Brown and Pilsbry

Pl. 78, figs. 1, 2

1911. *Conus molis* Brown and Pilsbry, Acad. Nat. Sci. Philadelphia, Proc., vol. 63, p. 343, pl. 23, fig. 1.

Shell of medium size. Spire low and concave. Sides of body whorl flat in outline. Postnuclear whorls nine. Protoconch missing. Early postnuclear whorls tuberculate. Surface of single spire whorls flat, sometimes with indications of a few spirals. Growth lines not deeply opisthocyt. Suture sharply incised. Shoulder of body whorl rounded. Growth lines on body whorl shallowly prosocyt. Upper portion smooth, near base with weak spiral riblets. Anal notch shallow. Margin of outer lip thin. Aperture slightly broader anteriorly.

Remarks. — There are six specimens of this form, the largest of which (H 13814) measures 38.4 mm. in height and 25.3 mm. in diameter. The type and the specimens figured by Olsson (1922, pl. 2, figs. 1, 2) from the Gatún formation of Costa Rica and the one figured by Weisbord (1929, pl. 6, fig. 1) from the Miocene of Colombia, have by far larger dimensions than has the present material. Even if one considers these shells as young, the dimensions are not proportional. *C. molis* seems to have a higher spire, and its body whorl is more constricted towards the siphonal canal.

Comparisons. — The Miocene to Recent *C. proteus* Hwass is also a larger species. Specimens from Bowden, Jamaica, at hand mainly differ from these shells by their higher spire. *C. recognitus* Guppy (for nomenclatural remarks see Pflug, 1961, pp. 59-60) is also larger, has a higher spire, a much more rounded shoulder of the body whorl, and no coronations on the early postnuclear whorls. *C. medialira* Vokes (1938, p. 18, fig. 18) from the Springvale formation of Trinidad has a more concave spire, is larger, and has a deeper anal notch but agrees in several details with the present material. *C. aemulator* Brown and Pilsbry (1911, p. 342, pl. 23, fig.

9) from the Gatún formation of the Panamá Canal Zone is somewhat stouter than these shells, has spiral striae on the spire whorls, but lacks coronations on the postnuclear whorls.

Occurrence. — Re 1148, Re 1152, Re 1154, Re 1199.

Conus trajectorynis Maury

Pl. 78, figs. 3, 4

1910. *Conus trajectorynis* Maury, Bull. Amer. Paleont., vol. 4, No. 21, p. 5, pl. 1, fig. 6.

1937. *Conus trajectorynis* Maury, Gardner, U.S. Geol. Sur., Prof. Paper 142-F, p. 359.

Shell of medium to large size. Spire high, flat in profile. Body whorl practically flat in profile. Shoulder of body whorl rounded. Postnuclear whorls nine, the first four of them with inconspicuous coronations. Protoconch apparently consists of about two volutions. Spire whorls ornamented by a few spiral ribs and by weak, shallow opisthocyrt growth lines. Anal notch shallow. Margin of outer lip thin. Aperture slightly wider anteriorly. Oblique groove within aperture on posterior extremity of parietal region present. Spiral sculpture on body whorl prominent near base, weaker at center, and missing below shoulder. Growth lines on body whorl extremely shallowly prosocyrt, nearly orthocline in their middle portion. Siphonal fasciole inconspicuous.

Holotype. — Cornell University, Ithaca, New York.

Remarks. — Except the figured specimen there is a second less well-preserved shell (H 13816). Its rounded shoulders of the spire whorls are somewhat elevated over the appressed suture, thus closely resembling the spire on the original figure. The surface of the figured specimen is somewhat washed, so that the protoconch is not preserved.

Comparisons. — Gardner (1937, p. 359) compared *C. trajectorynis* with *C. sulculus* Dall (1896, p. 43). More similar, however, seems to be the large *C. maga* Vokes (1938, p. 19, fig. 17) from the Springvale formation of Trinidad. It differs mainly by its deep anal notch and its somewhat stouter outline. *C. colombiensis* Weisbord (1929, p. 57, pl. 5, fig. 12) from the Miocene of northern Colombia has a concave profile of the spire. The original figure is not sufficient for a better comparison. *C. federalis* Weisbord (1962, p. 426, pl. 40, figs. 5, 6) from the Playa Grande formation (Miocene-Pliocene) of the Cabo Blanco area, Venezuela, has a compar-

able general outline and similar growth lines but differs in several sculptural details.

Occurrence. — N.V.P. Blue No. 3892.

Distribution. — Recorded from the Chipola formation of Florida only.

Conus aristos, n.sp.

Pl. 78, figs. 5-7

Shell small to medium in size, slender. Spire high. Profile of spire straight or slightly concave. Body whorl somewhat constricted towards the base. Protoconch consists of about three smooth and relatively high volutions. Postnuclear whorls eight or nine. The first two or three postnuclear whorls carry a sculpture starting with axial riblets which develop after half a turn into nodes situated on a now appearing keel. This sculpture, however, may be weak. The succeeding whorls are flat to slightly concave in profile, unsculptured except for the opisthocyrt growth lines. Suture lying at some distance below the mostly somewhat keeled shoulder. The growth lines of the body whorl below the shoulder are shallowly prosocyrt. Lower part of body whorl sculptured by about a dozen spiral grooves which generally become larger towards the base. Anal notch not deep.

Holotype. — Basel Natural History Museum, No. H 13817.

Dimensions of holotype. — Height 24.0 mm., greatest diameter 9.0 mm.

Variability. — The profile of the spire is flat in most specimens, but there are others with considerable concavity. The deepness of the anal notch is not constant. The number of spiral grooves at the base of the body whorl may vary as well as their intensity.

Remarks. — The material consists of about 20 more or less well-preserved specimens. Four of them still have their protoconchs. Young shells are more slender than adult ones, especially if they are going to develop a spire with concave profile.

Paratypes have been sent to the British Museum (Natural History), the Paleontological Research Institution, Ithaca, New York, and the U. S. National Museum, Washington, D. C.

Comparisons. — The specimens are similar to *C. sophus* Olsson (1932, p. 154, pl. 16, figs. 6, 8, 9) from the lower Zorritos formation of Perú. They are more slender, the distance between suture and

shoulder is greater, and the spiral sculpture on the lower portion of the body whorl less prominent. According to Olsson *C. sophus* has only six postnuclear whorls. If his specimens were not adult ones, the present shells with eight postnuclear whorls and a correspondingly higher spire would approach them closely, Olsson's holotype measuring 16.2 mm. in height, and one of shells at hand with eight postnuclear whorls 24.6 mm. However, the above mentioned differences seem to justify a separation of both forms. According to Olsson's description the prominent protoconchs of his material, which have not been figured, are similar to such from Paraguaná with the exception that they have half a turn more than *C. aristos*. The Eocene *C. smithvillensis* Harris (1895, p. 55, pl. 4, fig. 2) from Texas has a strikingly similar general form. According to the original figure it mainly differs by its deeper prosocyrte growth lines below the shoulder of the body whorl and the conspicuous coronations on the young postnuclear whorls. The protoconch of *C. waccamawensis* B. Smith (1930, p. 286, figs. 9-12) from the Pliocene of South Carolina (type locality), the Miocene of North and South Carolina and the Pliocene of Florida, is more conical in outline. The diameter of the first postnuclear whorl exceeds that of the last nuclear volution much more than in *C. aristos* where they may be nearly equal. Smith distinguished between a curved and an angulated type of subsutural flexure, *C. waccamawensis* belonging to the latter and *C. aristos*, to the former. If one follows his suggestion that these two types might be used for subgeneric grouping, the two species would be but superficially related. This seems to be confirmed by the growth lines below the shoulder of the body whorl which are nearly orthocone. The distance between suture and posterior shoulder of adult whorls is always greater in *C. aristos*, and its spiral ornamentation never covers the whole body whorl. The latter, however, does not seem to represent a reliable criterion as shown by Olsson and Harbison's figures (1953, pl. 26, figs. 4-1d). *C. aristos* is more slender than the Recent *C. floridanus* Gabb (1869, p. 195, pl. 15, fig. 4) from the Tampa Bay, Florida, which reaches a larger size, and has more postnuclear whorls. The Recent *C. arcuatus* Broderip and G. B. Sowerby I from Mazatlán, México, which has been refigured by Hanna and Strong (1949, pl. 5, figs. 2-4) is larger, has more

postnuclear whorls and a stronger spiral ornamentation. The first four of its postnuclear whorls carry strong nodes on their keels, whereas in *C. aristos* only the first one or two postnuclear volutions are sculptured.

Occurrence. — N.V.P. Blue No. 3892, Re 1148, Re 1155.

Conus aff. imitator Brown and Pilsbry

Pl. 78, fig. 12

1911. *Conus imitator* Brown and Pilsbry, Acad. Nat. Sci., Philadelphia, Proc., vol. 63, p. 342, pl. 23, fig. 4.

Remarks. — The following are the differences between *C. imitator* and the present specimens: the prosocyrte growth lines on the body whorl are bent stronger on these shells. The first postnuclear whorls are not ornamented by beads as in *C. imitator*. The spiral ornamentation on the lower half of the body whorl consists partly of triple or double riblets. The Paraguaná shells have fewer spirals with about equal interspaces in the upper part. In a few cases the interspaces carry a faint secondary spiral. The profile of the spire tends to be less concave in specimens from Paraguaná. The general outline of our shells and the material figured by Toulou (1911, pl. 31, fig. 23) as *C. dalli* is similar.² Most typical is the often sharply keeled shoulder. The sides of the body whorl of the present shells are nearly flat, those of Toulou's figures slightly constricted towards the base. According to Toulou the protoconch consists of three volutions. None is preserved in the material at hand. The opisthocyrte growth lines above the shoulder seem to have about the same deepness. The distance between suture and shoulder may become larger with increasing age, but this is not a rule. Hardly recognizable spiral threads may be present on the whorls of the spire.

Whether the original figure of *C. almagrensis* Böse (in Böse and Toulou 1910, p. 253, pl. 13, fig. 28) from the Isthmus of Tehuantepec, México, represents a young stage of *C. imitator* or not, cannot be decided with the help of this figure alone. According to Böse it has only two nuclear volutions.

Occurrence. — N.V.P. Blue No. 3892, Re 1148.

Conus talis, n.sp.

Pl. 78, figs. 8-11

Shell small, stout. Spire moderately high, flat in profile as

²Toulou's *C. dalli* represents immature *C. imitator*.

a whole, the single whorls, however, with a considerable concavity. Protoconch high, consists of three smooth volutions, the two last of which have nearly the same diameter. Postnuclear whorls nine, none of them carrying beads on the sometimes sharply keeled shoulder. Ornamentation above shoulder of deep opisthocyrta growth lines which produce the anal notch but of no spiral threads. Surface of body whorl nearly straight, slightly convex in the upper part, more or less concave towards the base. Siphonal fasciole somewhat bulging. Spiral sculpture on lower portion of body whorl consists of ten to 14 grooves of varying width, the uppermost ones generally narrow with wide interspaces followed medially by wide grooves, which become narrow towards the siphonal fasciole. Growth lines below shoulder prosocyrta. When especially conspicuous they may set off the spiral grooves.

Holotype.—Basel Natural History Museum, No. H 13824.

Dimensions of holotype.—Height 28.7 mm., greatest diameter 16.0 mm.

Variability.—The concavity of the spire whorls is not constant. Young postnuclear whorls have a keel somewhat projecting over the suture. Later the suture may be appressed to the keel or there may be a distance between them. It is observed in a single specimen that both situations may occur simultaneously, *i.e.* that the suture is appressed to the shoulder, then turns anteriorly for some distance, and finally rejoins the shoulder. Details of the spiral sculpture on the body whorl are considerably variable.

Remarks.—The material consists of about 80 shells which are constant in general outline. Protoconchs and the margin of the outer lip are rarely preserved.

Paratypes have been sent to the British Museum (Natural History), the Paleontological Research Institution, Ithaca, New York, and the U.S. National Museum, Washington, D.C.

Comparisons.—*C. imitator* Brown and Pilsbry (1911, p. 342, pl. 23, fig. 4) from the Panamá Canal Zone is a larger species with a slightly concave spire. Its first postnuclear whorls are tuberculate in contrast to *C. talis*. *C. talis* has no spiral threads on the spire whorls and is stouter than *C. imitator s.str.* *C. imitator lius* Woodring (1928, p. 209, pl. 10, figs. 5, 6) from Bowden, Jamaica, topotypes of which are at hand, mainly differs by its larger size. Young

individuals of it have the whole surface of the body whorl spirally striated, whereas in *C. talis* this ornamentation always remains restricted to the lower part of the body whorl. *C. talis* tends to be stouter. *C. floridanus costaricensis* Olsson (1922, p. 45, pl. 3, figs. 3, 9) from the Gatún formation of Costa Rica is larger and more slender than *C. talis* and shows spiral threads on the spire whorls. It closely resembles *C. imitator*, as stated by Olsson, and might prove to belong to that species. *C. bocapanensis* Spieker (1922, p. 38, pl. 1, fig. 3) from the lower Zorritos formation of Perú is also a larger and more slender species with a spiral ornamentation covering the whole body whorl, although weaker in its upper part. The spire whorls of *C. vauhanensis* Mansfield (1935, p. 20, pl. 1, fig. 8) from the Arca Zone (upper middle Miocene) of Florida carry spiral threads. The holotype has nearly the double dimensions of the holotype of *C. talis*, an inconspicuous spiral sculpture around the siphonal canal, but otherwise similar proportions. *C. chipolanus* Dall (1896, p. 42) from the Chipola formation of Florida differs by its concave spire, the more conspicuous constriction above the siphonal canal, and in details of its spiral sculpture. A spire similar to that of *C. talis* has the Recent *C. bermudensis lymani* Clench (1942, p. 35, pl. 13, fig. 3) from Florida. Further comparison is not possible with the help of the original description and figure alone.

Occurrence. — N.V.P. Blue No. 3892, Re 1148, Re 1155, Re 1199.

Family **TEREBRIDAE**

Genus **TEREBRA** Bruguière

Bruguière, 1789, Encycl. Méth. Histoire naturelle des Vers, vol. 1, p. 15.

Type species (by monotypy, Lamarck, 1799, Mém. Soc. Hist. Nat. Paris, p. 71), *Buccinum subulatum* Linné.

Subgenus **PARATEREBRA** Woodring

Woodring, 1928, Carnegie Inst. Wash., Pub. 385, p. 135.

Type species (by original designation), *Terebra texana* Dall.

According to Clench (1939, p. 8) *T. texana* Dall is a synonym of *T. flammea* Lamarck.

Terebra (Paraterebra) inaequalis G. B. Sowerby I Pl. 78, figs. 14, 15;
Pl. 79, figs. 1-3, 9

1850. *Terebra inaequalis* G. B. Sowerby I, Quart. Jour. Geol. Soc. London, vol. 6, p. 47.

1896. *Terebra gabbi* Dall, U.S. Nat. Mus., Proc., vol. 18, p. 34.
1903. *Terebra gabbi*, Dall, Dall, Wagner Free Inst. Sci., Trans., vol. 3, pt. 6, pl. 59, fig. 31.
1917. *Terebra gabbi* Dall, Maury, Bull. Amer. Paleont., vol. 5, No. 29, p. 23.
Not 1917. *Terebra inaequalis* Sowerby, Maury, *ibid.*, p. 29, pl. 4, fig. 2.
1928. *Terebra inaequalis* Sowerby, Woodring, Carn. Inst. Wash., Pub. 385, p. 136.
1934. *Terebra inaequalis* Sowerby, Rutsch, Abh. Schweiz. Pal. Ges., Bde. 54 and 55, p. 109.
1937. *Terebra (Paraterebra) inaequalis* Sowerby, Gardner, U.S. Geol. Sur., Prof. Paper 142-F, p. 279.

Shell large, divided in a younger strongly sculptured part and an older part with disappearing sculpture. Protoconch missing. Young whorls sculptured by a subsutural band which is divided into two parts by a narrow incised line. Band carrying numerous prosocline axials. Area between subsutural band and suture bearing ribs nearly parallel to shell axis. With increasing age the ornamentation gradually disappears except the subsutural band which is marked even in old stages. Growth lines opisthocyrt on adult whorls, somewhat irregular on gerontic whorls. Siphonal canal long. Constriction behind siphonal fasciole. Outer lip bent outwards in upper third of gerontic whorls. Parietal callus thick. Columella with a basal fold in old stages but with an additional broad swelling in younger stages.

Lectotype.—British Museum (Natural History), No. GG 20006 (Heneken collection). Yaque River, Dominican Republic.

Dimensions of lectotype.—Height 55.1 mm., greatest diameter 12.8 mm.

Variability.—The two parts of the subsutural band separated by an incised line may be equal in width. The lower portion is generally narrower on the present specimens than on the lectotype. The subsutural band on late whorls is more or less prominent. The diameter of the whorls may increase gradually or abruptly where the sculpture begins to disappear. A sectioned specimen clearly shows the transition zone from a uniplicate to a biplicate columella.

Remarks.—The type material of *T. inaequalis*, *T. sulcifera*, and *T. bipartita* is at hand. C. P. Nuttall of the British Museum (Natural History) in a letter dated 23rd July 1963 wrote: "My

colleague Mr. Sealy informs me that the so-called 'paratypes' were in the Heniker Collection, but there is no proof that Sowerby studied them." The lectotype shows the younger stages only; its adult whorls with obsolete sculpture are missing. The only paralectotype (Brit. Mus. (NH) No. GG 20007), the status of which as paralectotype remains questionable according to the above quotation, shows the transition zone between sculptured whorls and adult whorls with disappearing sculpture. A sharp basal columellar fold is recognizable at the aperture and an additional swelling at the broken adapical end. The diameter of the whorls increases rapidly.

Comparisons. — The Recent type species *T. texana* Dall (1898a, p. 45; 1902, p. 502, pl. 29, fig. 8) (= *T. flammca* Lamarck) is difficult to distinguish from *T. inaequalis* with Dall's figure alone. The diameter of the whorls seems to increase regularly. The sculpture disappears later in *T. texana*. The Pliocene *T. elena* Pilsbry and Olsson (1941, p. 13, pl. 1, figs. 1, 9) from western Ecuador is the only species showing the conspicuous subsutural bands on adult whorls as they may occur in the present material. The area between suture and subsutural band is more concave in *T. elena*. The sculptured younger whorls are not sufficiently described to allow a comparison. It is only compared to *T. robusta* Hinds (1844b, p. 149) = *T. macrospira* Li (1930, p. 273, pl. 8, fig. 66). *T. elena* reaches a considerably larger size than the Paraguaná specimens. *T. isaacpetiti* Maury (1917, p. 31, pl. 4, fig. 4; 1925, p. 184), which is also well figured by Perrilliat Montoya (1960, pl. 4, figs. 15, 16), is larger and has sculptured adult whorls. Its diameter increases gradually. *T. lepta* Woodring (1928, p. 136, pl. 3, fig. 1) from the Bowden formation of Jamaica does not seem to have the strongly sculptured younger whorls, and there is no tendency to develop convex whorls. The subsutural band is much less accentuated than in *T. inaequalis*. Somewhat similar in general aspect is *T. calhounensis* Maury, (1910 p. 4, pl. 1, fig. 3) from the Chipola formation of Florida, but the diameter of the whorls increases regularly, and the subsutural band is undivided. Its sculpture becomes obsolete in later stages. One of the specimens at hand differs from the rest of the material in having an undivided subsutural band (see pl. 79, fig. 2) like *T. calhounensis*, which is inconspicuous on later

whorls, and in having the tendency to develop convex whorls. The worn shell described by Woodring (1928, p. 137, pl. 3, fig. 2) as *T. (Paraterebra)* spec. from Bowden approaches the last whorls of this extreme specimen. The Recent *T. dumbauldi* Hanna and Hertlein (1961, p. 77, pl. 6, fig. 2, pl. 7, figs. 2-5) from the Eastern Pacific has a similar general outline. It is a somewhat larger species, and the area below the subsutural band is not impressed, so that the later whorls have a regularly convex surface. The sculpture of the younger whorls is different.

Occurrence. — N.V.P. Blue No. 3892, Re 1152, Re 1154.

Distribution. — Miocene of the Dominican Republic.

***Terebra (Paraterebra) sulcifera* G. B. Sowerby I** Pl. 78, figs. 13, 16;
Pl. 79, figs. 11, 12, 17

1850. *Terebra sulcifera* G. B. Sowerby I, Quart. Jour. Geol. Soc. London, vol. 6, p. 47.

1876. *Terebra sulcifera* Sowerby, Guppy, *ibid.*, vol. 32, p. 525, pl. 29, fig. 8.

1917. *Terebra sulcifera* Sowerby, Maury, Bull. Amer. Paleont., vol. 5, No. 29, p. 22, pl. 3, figs. 12, 13.

1917. *Terebra bipartita* Sowerby, Maury, *ibid.*, p. 23, pl. 3, fig. 14.

1917. *Terebra inaequalis* Sowerby, Maury, *ibid.*, p. 29, pl. 4, fig. 2.

1922. *Terebra bipartita* Sowerby, Olsson, Bull. Amer. Paleont., vol. 9, No. 39, p. 35, pl. 1, figs. 1, 2.

? 1922. *Terebra cf. naitensis* Dall, Olsson, *ibid.*, p. 35, pl. 1, fig. 3.

1925. *Terebra sulcifera* Sowerby, Maury, Bull. Amer. Paleont., vol. 10, No. 42, p. 182, pl. 32, fig. 3.

1925. *Terebra bipartita* Sowerby, Maury, *ibid.*, p. 183, pl. 32, fig. 2.

? 1929. *Terebra bipartita* Sowerby, Weisbord, Bull. Amer. Paleont., vol. 14, No. 54, p. 52, pl. 6, fig. 2.

1937. *Terebra (Paraterebra) sulcifera* Sowerby ?, Gardner, U.S. Geol. Sur., Prof. Paper 142-F, p. 278, pl. 38, fig. 1.

Shell moderately large; sculpture becoming indistinct with increasing age. Profile of whorls straight. Protoconch missing. Spiral sculpture consists of a conspicuous subsutural band followed anteriorly by a sharply incised line. This line is followed by a second smaller band, which may, however, disappear. The remaining area of the whorl may lack any spiral sculpture or carry a few faint spiral grooves especially near the anterior suture. The prosocline axials on the subsutural bands are discontinuous in young stages, but become continuous later on, and form numerous close set opisthocyrt growth lines on adult whorls. Siphonal canal long. Columella with two plicae in younger, with one fold only in gerontic stages. Apical angle constant.

Lectotype. — British Museum (Natural History), No. GG 20004 (Heneken Collection). Yaque River, Dominican Republic.

Dimensions of lectotype. — Height 55.1 mm., greatest diameter 20.4 mm.

Variability. — The most variable feature of this species is the second subsutural band. It is always smaller than the upper one. All transitions of its size are represented in the present collection. In many cases it is missing at all, in others it is indicated by a narrow swelling. A few specimens show no second subsutural band in young stages but develop a distinct swelling on later whorls. A specimen, however, on which all transitions are united, is not represented.

Remarks. — The lectotype is a fragment of about three gerontic whorls which are somewhat convex. The indistinct spiral sculpture consists of a band situated at about the center of the whorl, and representing the second subsutural band, which is bordered by two shallow grooves. The numerous opisthocyrt growth lines are close set and fine. The suture is undulating probably due to gerontism. The only paralectotype (Brit. Mus. (NH) No. GG 20005) (see remarks under *T. inaequalis*) consists of a fragment of about four adult whorls. It shows the same sculpture as the lectotype. The columella has one basal fold at the aperture, but on its adapical end an inconspicuous swelling is developed above it. It might be possible, therefore, that the columella loses one of its two folds of the young stages with increasing age.

It is unfortunate that the type material does not show the young stages. On the other hand no gerontic whorls are preserved in the rich material at hand, so that the ontogenetic development postulated here must remain hypothetical, until an undamaged old individual is at hand. However, the specimen figured by Maury (1917, pl. 3, fig. 12) from the Dominican Republic has adult whorls perfectly agreeing with those of the paralectotype and younger whorls nearly identical with such from Paraguaná.

As a whole the sculpture of the material from Paraguaná is coarser and somewhat more accentuated than that of the type material.

Comparisons. — If my statements of variability are correct, the form from Springvale described by Rutsch (1942, p. 170) as *T.*

aff. *sulcifera* really represents *sulcifera*. Its second subsutural band is rudimentarily developed, and the groove separating it from the upper band shallow and indistinct. *T. isaacpetiti* Maury (1917, p. 31, pl. 4, fig. 4; 1925, p. 184) is a larger species with a much stronger developed second subsutural band. *T. inaequalis* G. B. Sowerby I has a certain resemblance with *T. sulcifera* in young stages, but its second subsutural band is wider, and the lowest part of the whorl lies deeper when viewed in profile. Rutsch (1934, p. 109) pointed out the differences between his *T. lehneri* and *T. sulcifera*. *T. lehneri* with its flat whorls stands closer to *T. unilineata* (Conrad) (1841, p. 345, pl. 2, fig. 4) from the Duplin marl of North Carolina (see also Gardner, 1948, p. 275, pl. 38, figs. 35, 36). *T. haitensis* Dall (1896, p. 35; 1903, pl. 59, fig. 30) from the Miocene of the Dominican Republic mainly differs by its lesser apical angle. Maury (1917, pl. 4, fig. 3) figured a specimen with flat whorls. The probably Pleistocene large *T. albemarlensis* Dall and Ochsner (1928, p. 99, pl. 2, fig. 1) from the Galapagos Islands has one broad subsutural band, and its sculpture becomes only slightly indistinct with increasing age. Its axial riblets are nearly orthocline. Young specimens of the present material closely resemble *T. subsulcifera*. Brown and Pilsbry (1911, p. 339, pl. 22, fig. 7) from the Gatún formation of the Isthmus of Panamá. *T. subsulcifera* seems to have coarser axials. The type figured by Brown and Pilsbry has two subsutural bands, the specimen figured by Cossmann (1913, pl. 1, fig. 25) only one.

Occurrence.—N.V.P. Blue No. 3892, Re 1148, Re 1155, Re 1199.

Distribution.—Miocene, Dominican Republic. Bowden formation, Jamaica. Springvale formation, Trinidad. Chipola and Shoal River formations, Florida.

Subgenus **STRIOTEREBRUM** Sacco

Sacco, 1891, I Molluschi dei terreni terziarii del Piemonte e della Liguria, pt. 10, p. 33.

Type species (by original designation), *Terebra basteroti* Nyst.

***Terebra (Strioterebrum) ulloa* Olsson**

Pl. 79, figs. 13-15

1932. *Terebra (Strioterebrum) ulloa* Olsson, Bull. Amer. Paleont., vol. 19, No. 68, p. 147, pl. 15, figs. 1, 2.

1951. *Terebra* (*Strioterebrum*) *ulloa* Olsson, Marks, Bull. Amer. Paleont., vol. 33, No. 139, p. 123.

Shell of medium size. Nuclear whorls not preserved. Subsutural band occupying about a quarter of a whorl. Early whorls slightly convex, later whorls straight in profile. Axial sculpture consists of low, widely spaced ribs, which are much more prominent in young stages. With increasing age they may become irregularly spaced and unequal in strength. They have an axial direction on the anterior part of the whorl, turn towards a spiral direction near the more or less deep groove below the subsutural band, and are parallel to the shell axis again on the subsutural band. The spiral sculpture consists of several regularly or irregularly spaced threads. In young stages they may attain the same strength as the axial ribs, thus causing a reticulate sculpture, but on later whorls they are always less conspicuous. At their intersection with the axial ribs there are but weak nodes. The first spiral below the subsutural band is generally more prominent than the others. Spiral sculpture on subsutural band weak or absent. Outer lip broken, inner lip with callus. Siphonal fasciole prominent, bordered posteriorly by a sharp keel. Siphonal canal somewhat notched behind. Columella with one low fold.

Holotype. — Pal. Res. Inst., Ithaca, New York, No. 2263.

Variability. — There are several features undergoing considerable variation. The spiral threads may be regularly or irregularly spaced. They may be prominent even on the last whorl or nearly disappear. Their number varies between four and eight. The suture is more or less furrowed. If it is deep, the subsutural band forms a shoulder. The subsutural band may carry spiral sculpture or not. The sulcus below the subsutural band may be sharply incised and relatively wide, or less conspicuous. The axial ribs may cross them with undiminished strength or be completely interrupted.

Remarks. — The material consists of about 40 well-preserved specimens. In the original description Olsson stated that the columella is smooth, without folds. One of the specimens has been sectioned. Its columella shows a low ridge situated on the lower half of a whorl. It forms the inner edge of the siphonal canal. The sharp keel bordering the siphonal fasciole does not continue into the aperture, but disappears at the point, where it meets the callus of the inner lip.

As pointed out by Woodring (1928, p. 134) and Pilsbry and Lowe (1932, p. 39) the number of columellar folds as a systematic criterion is not applicable to major groups. *T. ulloa* and *T. gatunensis* may serve as example for this statement: similar shape and sculpture but different number of columellar folds.

Comparisons.—Several species are described in the literature, which have the same general form and the same pattern of sculpture. The size of the shell and the intensity of single sculptural elements are the main features separating the different species. Closest related to *T. ulloa* is *T. gatunensis* Toula (1909, p. 705, pl. 25, fig. 14) from Panamá. Its spiral and axial sculptures are about equal in strength. The spiral sculpture of the latest whorl is much more prominent than in *T. ulloa*. Specimens from the Gatún formation of Costa Rica at hand show conspicuous nodes at the intersection points of spiral and axial ribs. *T. gatunensis* has two low columellar folds, *T. ulloa* only one. *T. gatunensis kugleri* Rutsch (1934, p. 106, pl. 8, figs. 18, 19; pl. 9, figs. 12, 13) from the Punta Gavilán formation of Falcón, Venezuela, (the types of which are at hand) is considerably larger, and has wider spiral ribs on the last whorl. *T. waltonensis* Gardner (1937, p. 282, pl. 38, figs. 8-10) from the Shoal River formation of Florida has also two low columellar folds. Its axial sculpture is more prominent than the spiral one as in *T. ulloa*, but the whorls seem to be more convex according to the original figures. The columella of *T. alaquacensis* Mansfield (1935, p. 15, pl. 1, fig. 1) from the *Arca* Zone (upper middle Miocene) of Florida is weakly biplicate. The whorls are somewhat convex, and there are less spiral ribs on a whorl. Specimens of the Recent *T. dislocata* (Say) (1822, p. 235) from Cuba at hand have lower whorls. The axial ribs on the subsutural band are much more conspicuous. Its columella is biplicate.

Occurrence.—N.V.P. Blue No. 3892, Re 1148, Re 1152, Re 1155, Re 1199.

Distribution.—Lower Zorritos formation, Perú. Subibaja formation (lower Miocene), southwestern Ecuador.

- Terebra (Strioterebrum) bipartita*** G. B. Sowerby I Pl. 79, figs. 4-6
 1850. *Terebra bipartita* G. B. Sowerby I, Quart. Jour. Geol. Soc. London, vol. 6, p. 47.
 1873. *Terebra bipartita* Sowerby, Gabb, Amer. Philos. Soc., Trans., new ser., vol. 15, p. 225.

1896. *Terebra (Acus) bipartita* Sowerby, Dall, U.S. Nat. Mus., Proc., vol. 18, p. 38.
 Not 1917. *Terebra bipartita* Sowerby, Maury, Bull. Amer. Paleont., vol. 5, No. 29, p. 23, pl. 3, fig. 14.
 Not 1922. *Terebra bipartita* Sowerby, Olsson, *ibid.*, vol. 9, No. 39, p. 35, pl. 1, figs 1, 2.
 Not 1925. *Terebra bipartita* Sowerby, Maury, *ibid.*, vol. 10, No. 42, p. 183, pl. 32, fig. 2.
 Not 1929. *Terebra bipartita* Sowerby, Weisbord, *ibid.*, vol. 14, No. 54, p. 52, pl. 6, fig. 2.
 ? 1937. *Terebra (Strioterebrum) bipartita* Sowerby, Gardner, U.S. Geol. Sur., Prof. Paper 142-F, p. 281, pl. 38, fig. 5.
 Not 1942. *Terebra (Paraterebra) cf. bipartita* Sowerby, Rutsch, *Verh. Naturf. Ges. Basel*. Bd. 54, p. 104.

Shell of medium size, slender. Whorls slightly convex in profile. Protoconch consists of about $2\frac{1}{4}$ volutions. Sculpture starts with nearly orthocline axials. The narrow subsutural band, which is well separated from the rest of the whorl by a conspicuous groove, carries numerous axials. Later two or three spirals are introduced. The rest of the whorl is ornamented by axials, which are prosocline in their upper portion on adult whorls, their number becoming larger with increasing age. The spiral sculpture consists of four to six flat spiral ribs, some of which may become divided by one or two grooves in later stages. The axial sculpture is dominating in young stages, where the spirals do not cause a knobbing of the axials. On adult whorls the axials produce knobs at the intersection points with the much heavier spirals. Siphonal canal moderately long, nearly straight. Parietal callus thin. Siphonal fasciole conspicuous, bordered by a strong, elevated ridge. Base of adult whorl sculptured by spirals, which are closer set than on the upper part of the whorl. Columella smooth within the aperture.

Lectotype. — British Museum (Natural History), No. GG 20008 (Heneken Collection). Yaque River, Dominican Republic.

Dimensions of lectotype. — Height 41.0 mm., greatest diameter 8.0 mm.

Remarks. — This species is not represented in the collection from Paraguaná. But a lectotype is designated here, since the type material is at hand, and because there has been considerable confusion concerning the morphology of this species. Besides the lectotype there are two well-preserved "paralectotypes" (Brit. Mus. (NH) Nos. GG 20009, GG 20010) (see also remarks under *T. inaequalis*).

Comparisons. — *T. alaquensis* Mansfield (1935, p. 15, pl. 1, fig. 1) from the *Arca* Zone (upper middle Miocene) of Florida is a smaller species with a broader subsutural band, more prominent axial sculpture in adult stages, and lower whorls. *T. berlinerae* Maury (1917, p. 34, pl. 4, figs. 7, 8) from the Cercado formation of the Dominican Republic is a similar species. It differs by its more convex whorls and the more conspicuous axial sculpture in adult stages. Toulou's type of *T. gatunensis* (1909, p. 705, pl. 25, fig. 14) is a somewhat less slender shell. Its subsutural band is broader, and there are more and narrower spirals. The whorls of *T. bipartita* are higher and more convex.

Distribution. — Miocene of the Dominican Republic. Shoal River formation of Florida ? Anderson (1927, p. 89) cited *T. bipartita* from the Miocene of northern Colombia.

***Terebra (Strioterebra)* species A**

Pl. 79, figs. 7, 8

Shell of small to medium size, slender. Nuclear whorls not preserved. Sculptured whorls straight to slightly convex in profile, increasing faster in diameter in young stages than later. Axial sculpture much more prominent than spiral sculpture. The axial ribs, numbering about 18 on one whorl, are straight or bent forward in their upper portion. On most shells they cross the strongly incised subsutural groove with reduced strength. Spiral sculpture on the subsutural band always weaker than on the remainder of the whorl, where the spirals number from five to seven. Outer lip broken. Inner lip callous. Siphonal fasciole bordered by a keel. Columella with a broad central swelling, sometimes showing indications of the development of two folds.

Variability. — The form of the columella is not constant in the material. On late whorls there is a single central swelling. On younger whorls a weak basal fold is present, which is followed in some specimens, after a shallow depression, by a broad inflation. One of the sectioned specimens shows two folds in young stages, but only a basal one later.

The spirals do not cross the axial ribs. Their intensity varies considerably. They may be relatively broad and closely set or narrow, inconspicuous and nearly disappear. There is one specimen (H 13842), whose growth has been interrupted by some accident. Its shell has been broken during life, but growth continued after

some time. Before the interruption the whorls are sculptured by six irregularly spaced weak spirals below the subsutural sulcus. After the cessation this spiral sculpture has almost disappeared. Hence: if such inconstancies occur in a single individual, the variability of terebrid species should not be restricted too much.

The width of the subsutural band, which may be smooth in the interspaces of the axial ribs or carry weak spirals, generally occupies about one-quarter of the height of the whole whorl. But on a number of the specimens it is broader. Those specimens with a wider subsutural band generally show a weaker spiral sculpture.

Comparisons.—The whorls of *T. bowdenensis* Woodring (1928, p. 138, pl. 3, figs. 3-8) are more convex than those of the present material. The subsutural band is narrower, and there are beads at the intersection points of spiral and axial sculpture. The columella seems to be similarly formed. The fragment called *Terebra* (*Strioterebrum*) species b by Woodring (1928, p. 140, pl. 3, fig. 15) from Bowden, Jamaica, seems to be closely related, if not identical, with the Paraguaná species. Its spiral sculpture on the subsutural band is conspicuous which is not the case on most specimens at hand. *T. bowdenensis meesmanni* Rutsch (1934, p. 108, pl. 9, figs. 14-16) from the Punta Gavilán formation of Falcón has more convex whorls, a narrower subsutural band without spirals and stronger axial ribs on whorls with comparable diameter. Its spirals are sometimes much broader. *T. gausapata* Brown and Pilsbry (1911, p. 340, pl. 22, figs. 8, 9) and *T. gausapata laevifasciola* Maury (1917, p. 27, pl. 3, figs. 19) are said to differ from each other by the presence or absence of spiral sculpture on the subsutural band respectively. Specimens of *T. gausapata* from the Gatún formation of the Panamá Canal Zone at hand have a greater apical angle, more convex whorls, deeper interspaces between the axial ribs and two sharp columellar folds. *T. waynesboroensis* Mansfield (1940, p. 203, pl. 27, fig. 23) from the Chickasawhay marl of Mississippi has inconspicuous spiral sculpture. There are several other species, which might be compared with the present material: *T. vughanensis* Mansfield, *T. blountensis* Mansfield, *T. waltonensis tribaka* Gardner, *T. loja* Pilsbry and Olsson, *T. pavonia* Olsson, and the Recent *T. brunneocincta* Pilsbry and Lowe.

Occurrence.—N.V.P. Blue No. 3892, Re 1148.

Terebra (Strioterebrum) species B

Pl. 78, fig. 17

Shell of small to medium size. Nuclear whorls not preserved. Subsutural band not distinct. Subsutural sulcus interrupted by the axial ribs which extend from suture to suture. Axial ribs, numbering about 19 on one whorl, nearly straight in young stages, but curved with increasing age. Spiral sculpture consists of five or six faint and irregularly spaced striae below the subsutural sulcus which do not cross the axial ribs. Whorls slightly convex in profile. Outer lip broken. Siphonal fasciole bordered by a sharply elevated keel. Siphonal canal not deeply notched. Columella probably smooth.

Remarks.— There is a single specimen of this form; $8\frac{1}{2}$ whorls are preserved (length 24.2 mm.). The number of axial ribs is constant on all the whorls.

Comparisons.— *T. ischna* Woodring (1928, p. 142, pl. 3, fig. 18; pl. 4, fig. 1) from Bowden, Jamaica, is a much smaller species. There are less axial ribs on a whorl, and the ribs are less curved. *T. rapta* Gardner (1937, p. 285, pl. 38, figs. 18, 19) from the Shoal River formation of Florida has about the same number of axial ribs, but they are oblique in an antispiral instead of a spiral direction. There is no spiral sculpture. *T. eskata* Gardner (1937, p. 283, pl. 38, fig. 13) from the Shoal River formation of Florida has less axial ribs which are somewhat depressed on the subsutural sulcus. It has no spiral sculpture. *T. zapotalensis* Olsson (1932, p. 148, pl. 15, fig. 5) from the Lower Zorritos formation of Perú has less but stronger axial ribs. It is smaller, and its whorls are slightly shouldered. *T. ballista* Mansfield (1937a, p. 77, pl. 1, fig. 3) from the Tampa limestone of Florida has straight whorls and a relatively conspicuous spiral sculpture. The group of *T. curvilineata* and its subspecies, including *T. sincera*, (see Martin, 1904, pp. 139-141) from the Miocene of Maryland has the same pattern of sculpture. Their whorls are straight in profile and not convex as in the present specimen.

Occurrence.— Re 1148.

Terebra (Strioterebrum) species C

Pl. 79, fig. 10

Remarks.— This form is represented by a single fragment of three whorls. It is similar to species B but differs in the following points: there are 30 to 34 axial ribs on one whorl with narrow interspaces. The subsutural sulcus is less deep. In the interspaces

just below the subsutural sulcus, there are slight elevations producing an obscure spiral rib but which does not influence the strength of the axial ribs. Spiral sculpture otherwise inconspicuous. Whorls straight in profile and somewhat shouldered. Columella smooth. Siphonal fasciole as in species B.

This form might be considered as an old stage of species B. But because the number of axials is constant in species B, it is unlikely that species B and C represent different ontogenetic stages of the same form.

Occurrence. — Re 1199.

Genus **HASTULA** H. and A. Adams

H. and A. Adams, 1853, *Genera of Recent Mollusca*, vol. 1, p. 225.

Type species (by subsequent designation, Cossmann, 1896, *Essais de Paléoconchologie comparée*, pt. 2, p. 53), *Buccinum strigilatum* Linné.

Hastula lissa, n.sp.

Pl. 79, fig. 16

Shell of medium size, slender. Whorls flat in profile, increasing regularly in diameter. Suture clearly incised. No spiral sculpture, not even fine spiral striae. Axial sculpture of young stages consists of nearly straight ribs numbering 17, which run with undiminished strength from suture to suture. With increasing age these ribs become more and more curved, and at the same time their strength is reduced on the lower half of the whorl. On the late whorls the axial ribs become inconspicuous even just below the suture. The only surface ornamentation on the remainder of the whorl then consists of curved incrementals. Outer lip and lowest part of siphonal canal broken. Siphonal canal probably not deeply notched. Inner lip with callus. Siphonal fasciole bordered by a keel. Columella probably nearly smooth.

Holotype. — Basel Natural History Museum, No. H 13845.

Dimensions of holotype. — Height 38.7 mm., greatest diameter 7.1 mm.

Remarks. — This species is represented by the holotype only, which is not a perfect shell of $11\frac{1}{2}$ whorls. The columella is visible at the aperture only which is generally not enough to determine its structure.

Comparisons.—*Hastula vautrini*, *nom. nov.*³ is a much smaller species. According to the original figure the axial ribs persist from suture to suture only on the three first preserved whorls, whereas in *H. lissa* they do so on more than five whorls. The aperture seems to be longer in *H. vautrini*. *H. homala* Woodring (1928, p. 143, pl. 4, fig. 5) is even smaller than *H. vautrini*. The early whorls of *H. gnomon* Keen (1943, p. 47, pl. 4, fig. 11) from the Californian Miocene increase more rapidly in diameter than the later ones. *H. simplex* (Conrad) (1829, p. 226, pl. 9, fig. 22) from the Miocene of Maryland has a greater apical angle and, according to Martin's figure (1904, pl. 40, fig. 10), a sharply limited inner lip which is not observable on the holotype of *lissa*. Another Miocene species from Maryland, *H. patuxentia* Martin (1904, p. 145, pl. 40, fig. 14), is similar in general form, but much smaller. It carries faint spiral striae. The Recent *H. cinerea* Born has a greater apical angle and less prominent axial sculpture. Its suture is much less incised than that of *H. lissa*.

Occurrence.—N.V.P. Blue No. 3892.

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³The name *jamaicensis* Woodring (1928, p. 143, pl. 4, fig. 4) is preoccupied by *Terebra jamaicensis* C. B. Adams, 1850 (Contributions to Conchology, No. 4, p. 58) which is a species of *Hastula* and has been figured by Clench and Turner (1950a, pl. 38, fig. 22). Neotype: Mus. Comp. Zool., No. 186151. As a new name for the Bowden species *Hastula vautrini* is proposed here.

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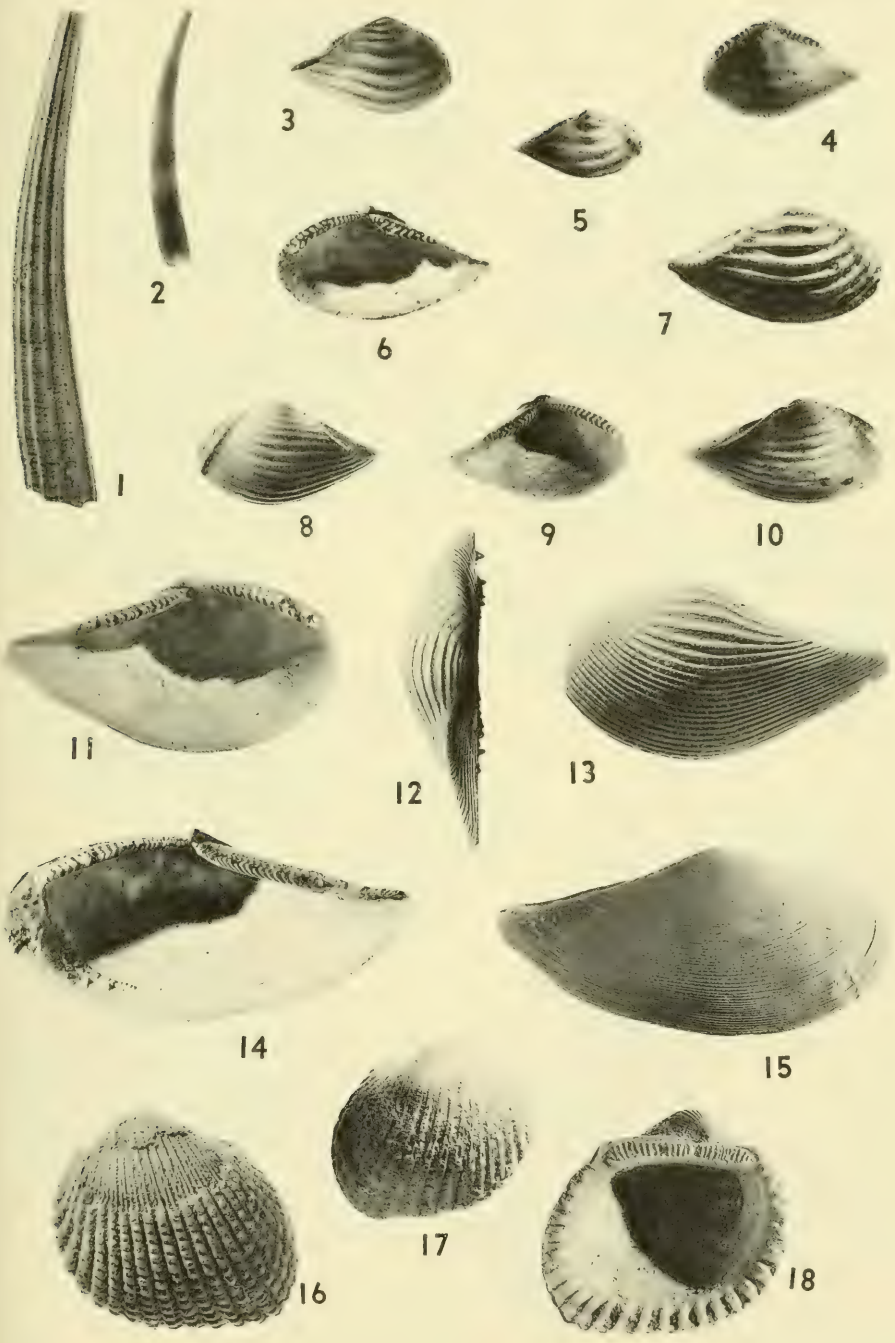
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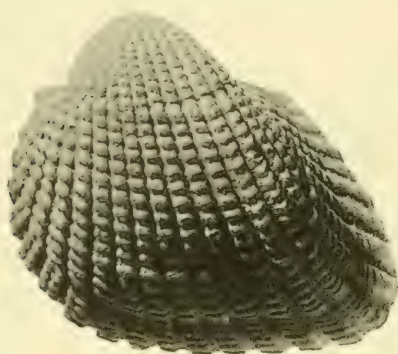
PLATES

If not otherwise specified the number accompanying each specimen refers to the catalogue of the Basel Natural History Museum (H includes Gastropoda, G Pelecypoda and Scaphopoda).

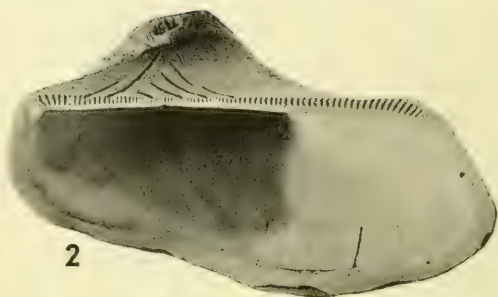
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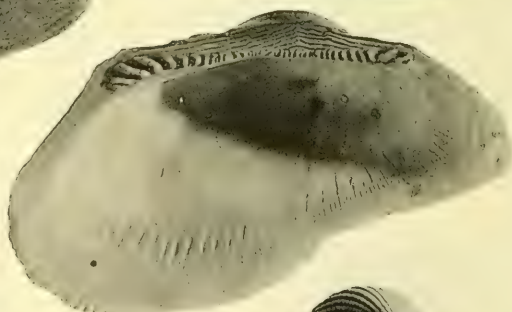
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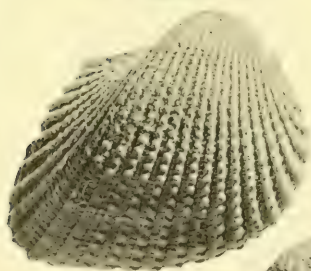
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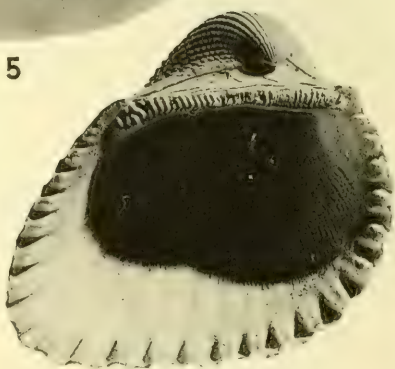
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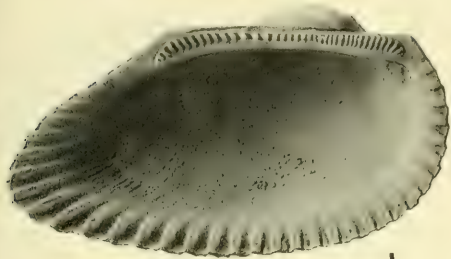
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EXPLANATION OF PLATE 51

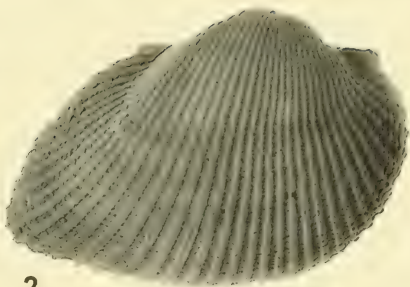
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7, 8. Anadara (Scapharca) tirantensis (H. K. Hodson)	430
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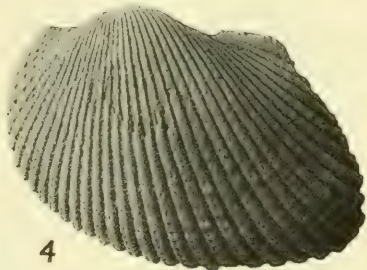
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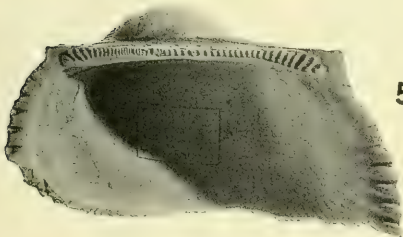
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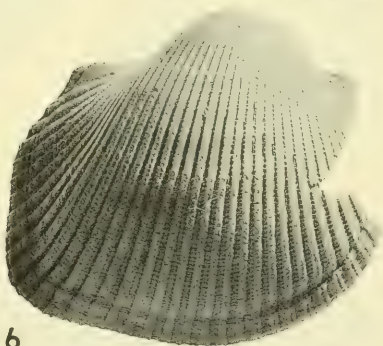
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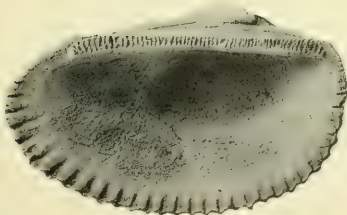
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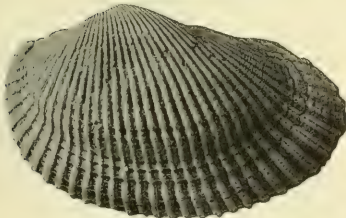
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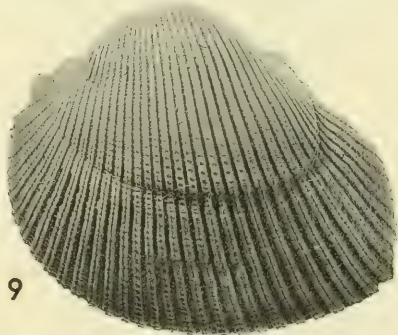
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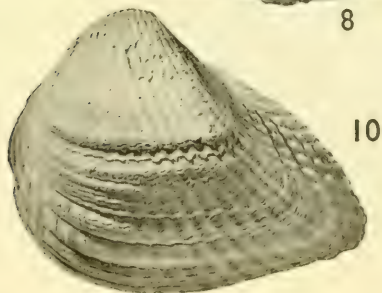
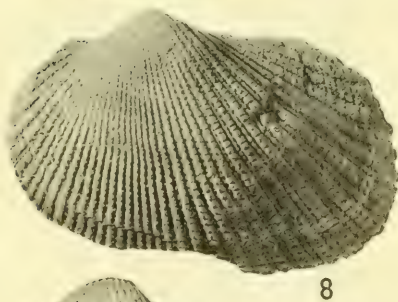
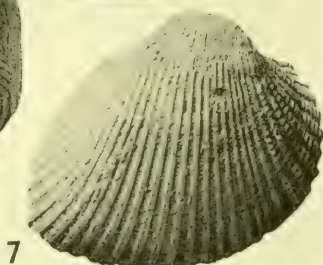
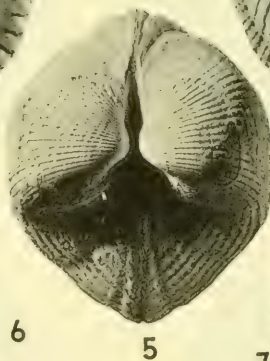
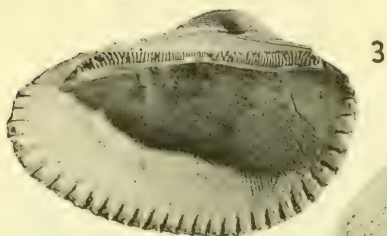
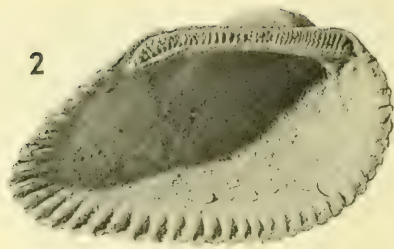
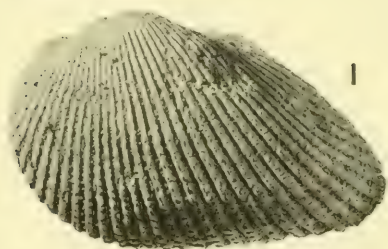
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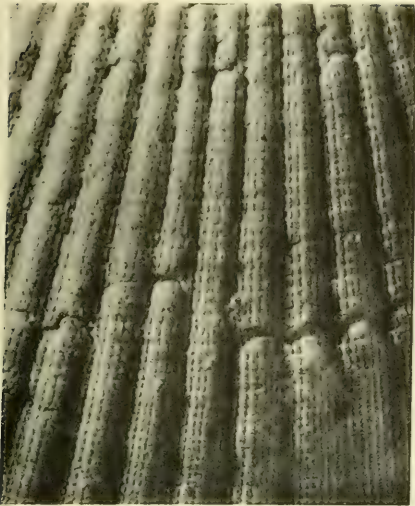


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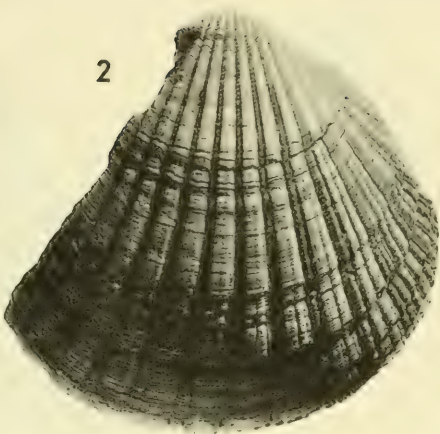
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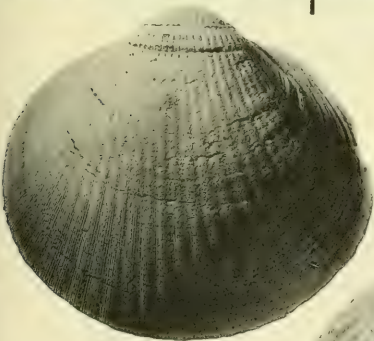
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7, 8. Plicatula cf. guppyi Woodring	441
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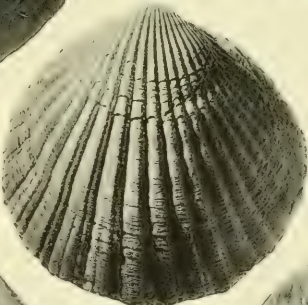
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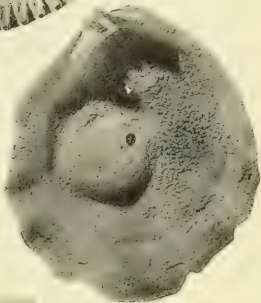
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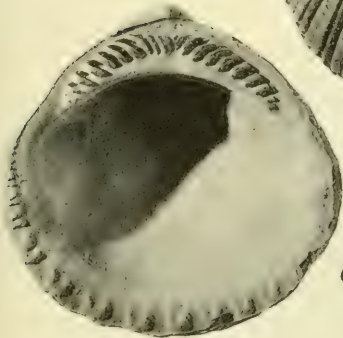
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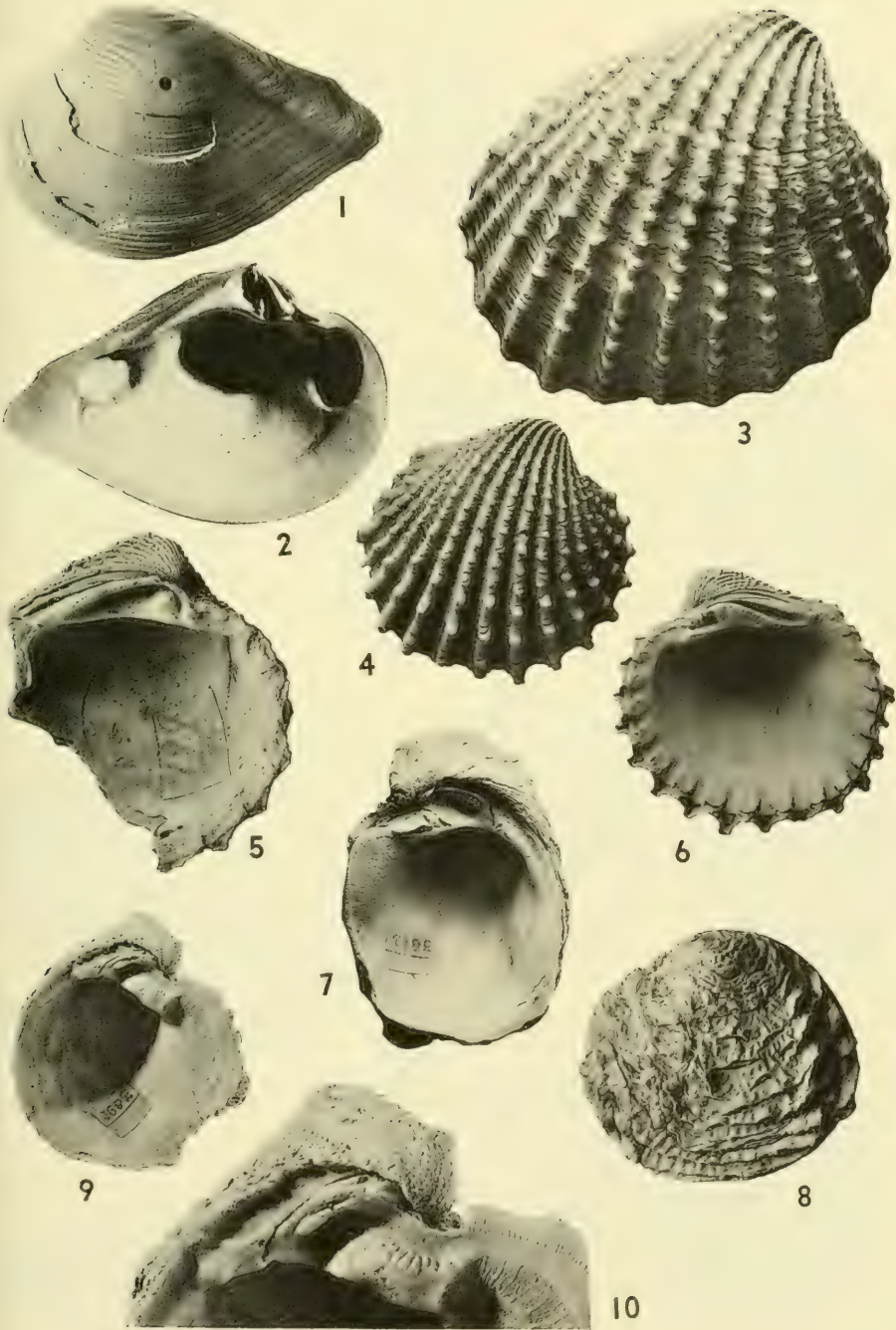


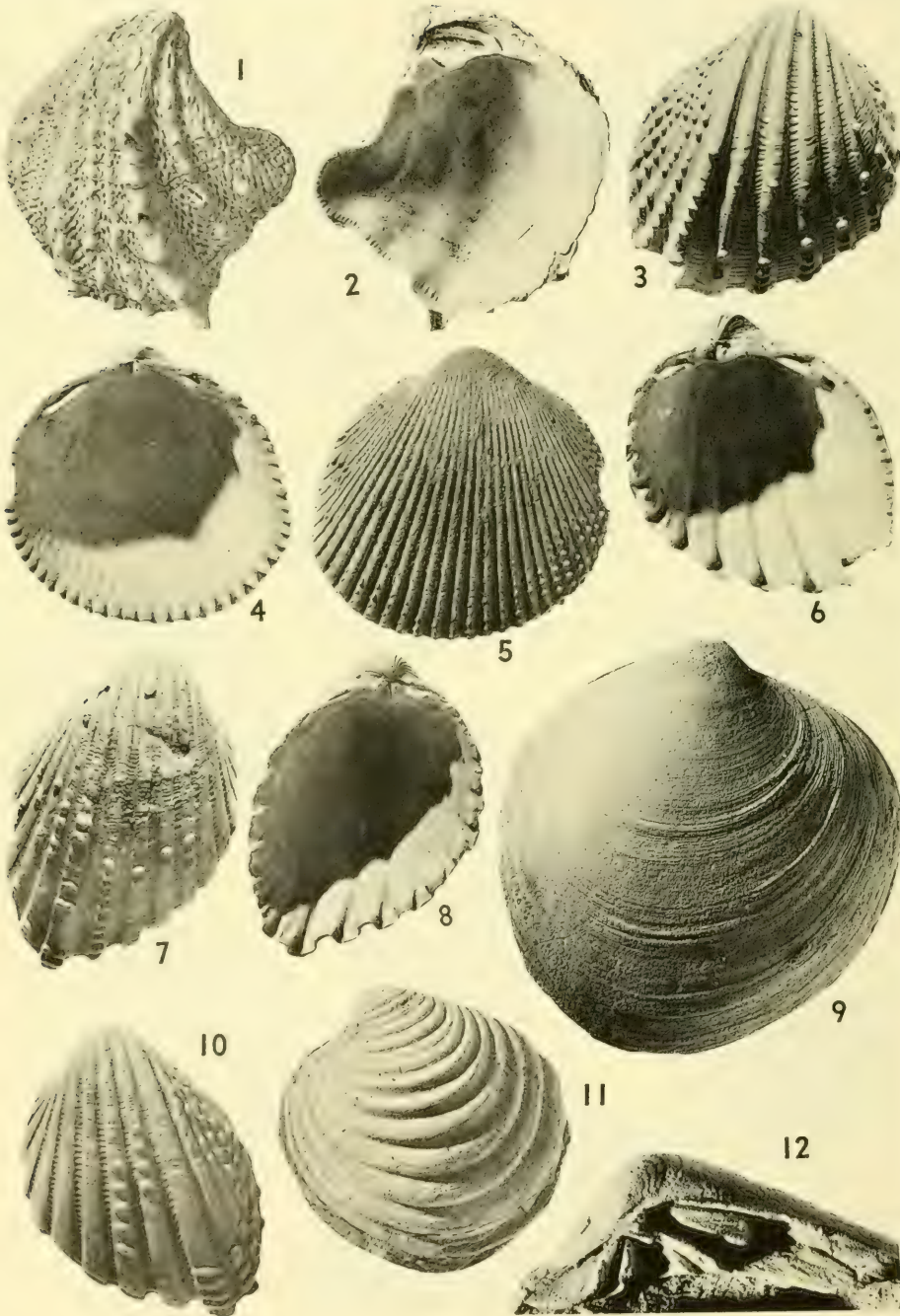
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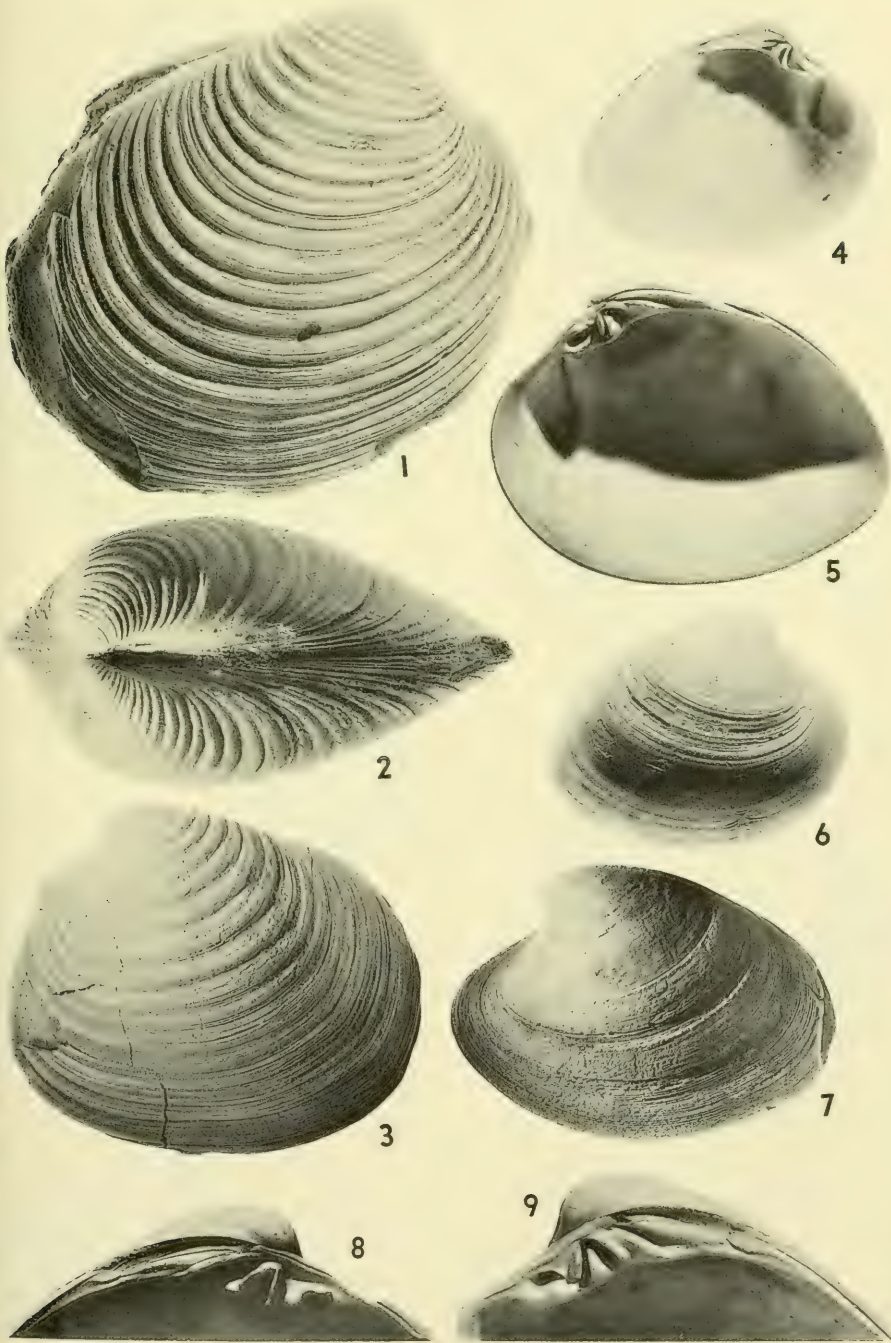


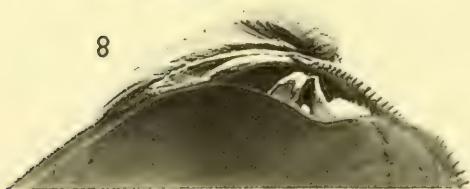
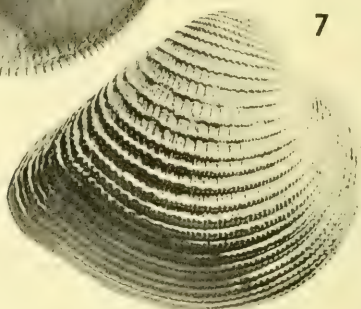
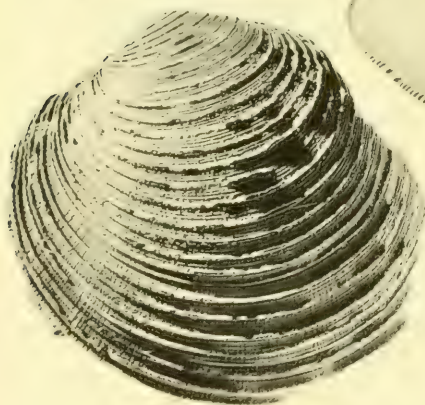
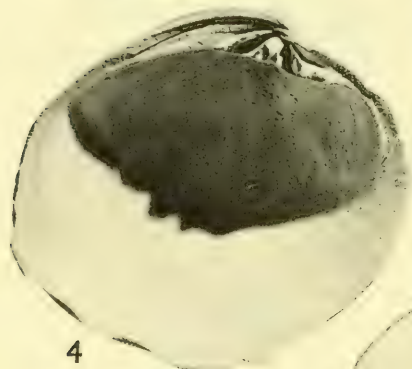
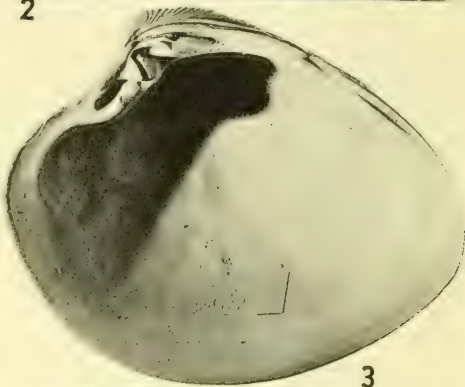
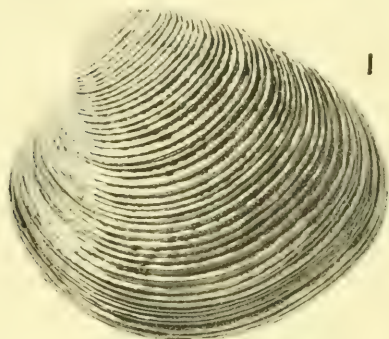
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4-6. Macrocallista maculata (Linné)	460
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8. Left hinge; X3; 3892. No. G 11339.	
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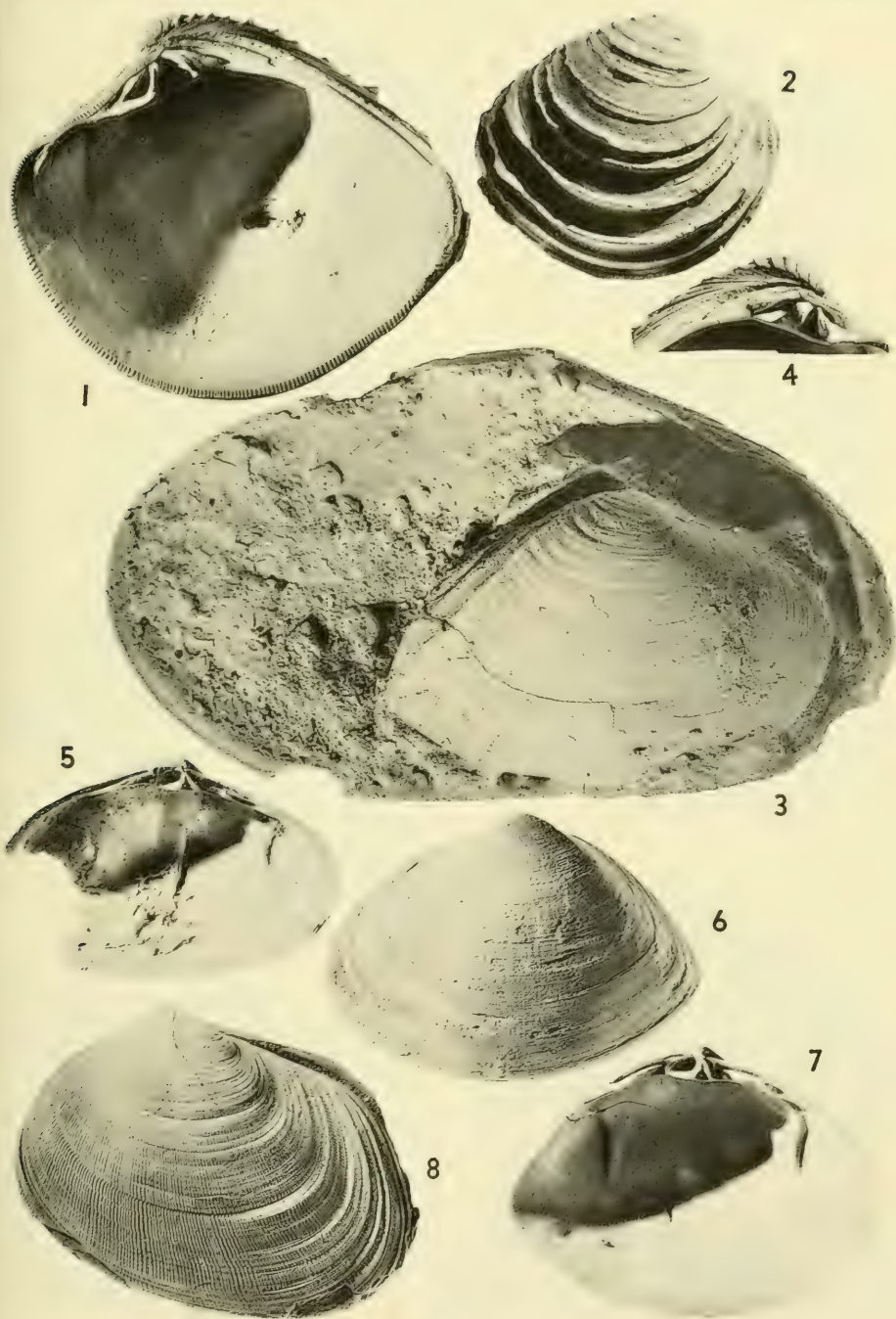


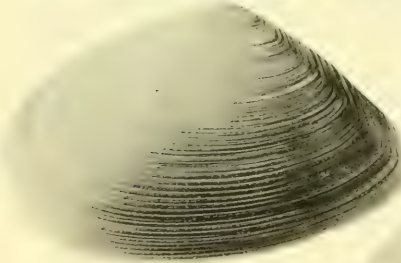
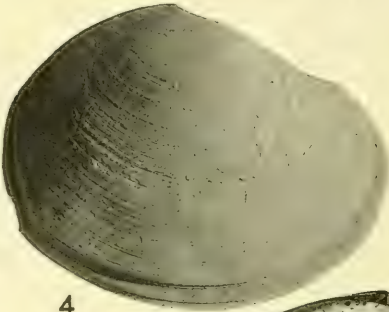
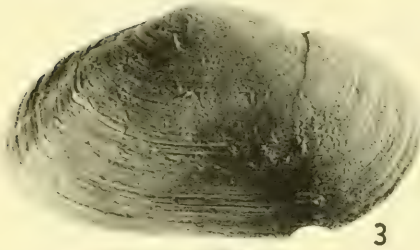
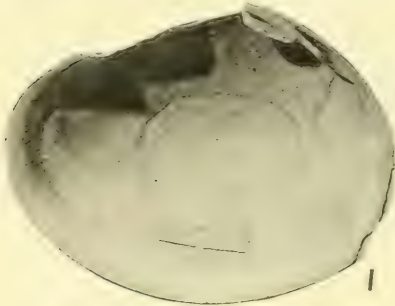
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8. Left hinge; X3. 3892. No. G 11348.	
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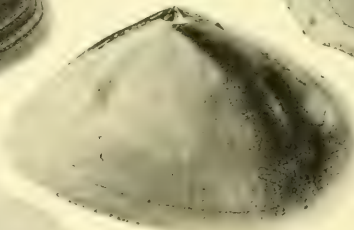
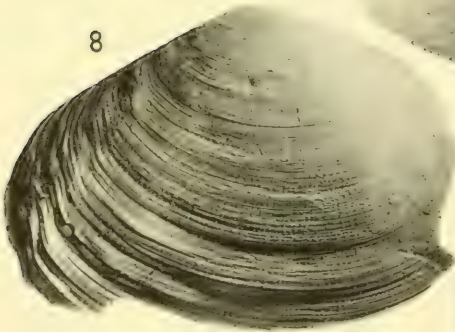
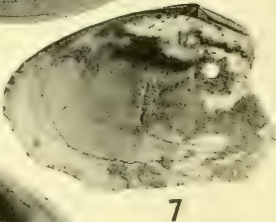
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1. Length 41.2 mm., height 34.4 mm., diameter 13.3 mm.; 3892. No. G 11350.	
2. Length 28.3 mm., height 25.0 mm., diameter 9.4 mm.; 3892. No. G 11351.	
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6, 7. Mactra (Mactrotoma ?) quirosana H. K. Hodson	470
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Length 56.2 mm., height 41.5 mm., diameter (both valves) 24.1 mm.; 3892. No. G 11357.	

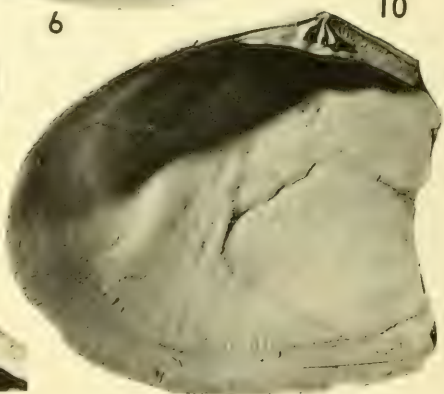
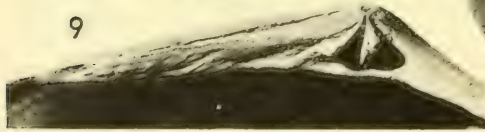




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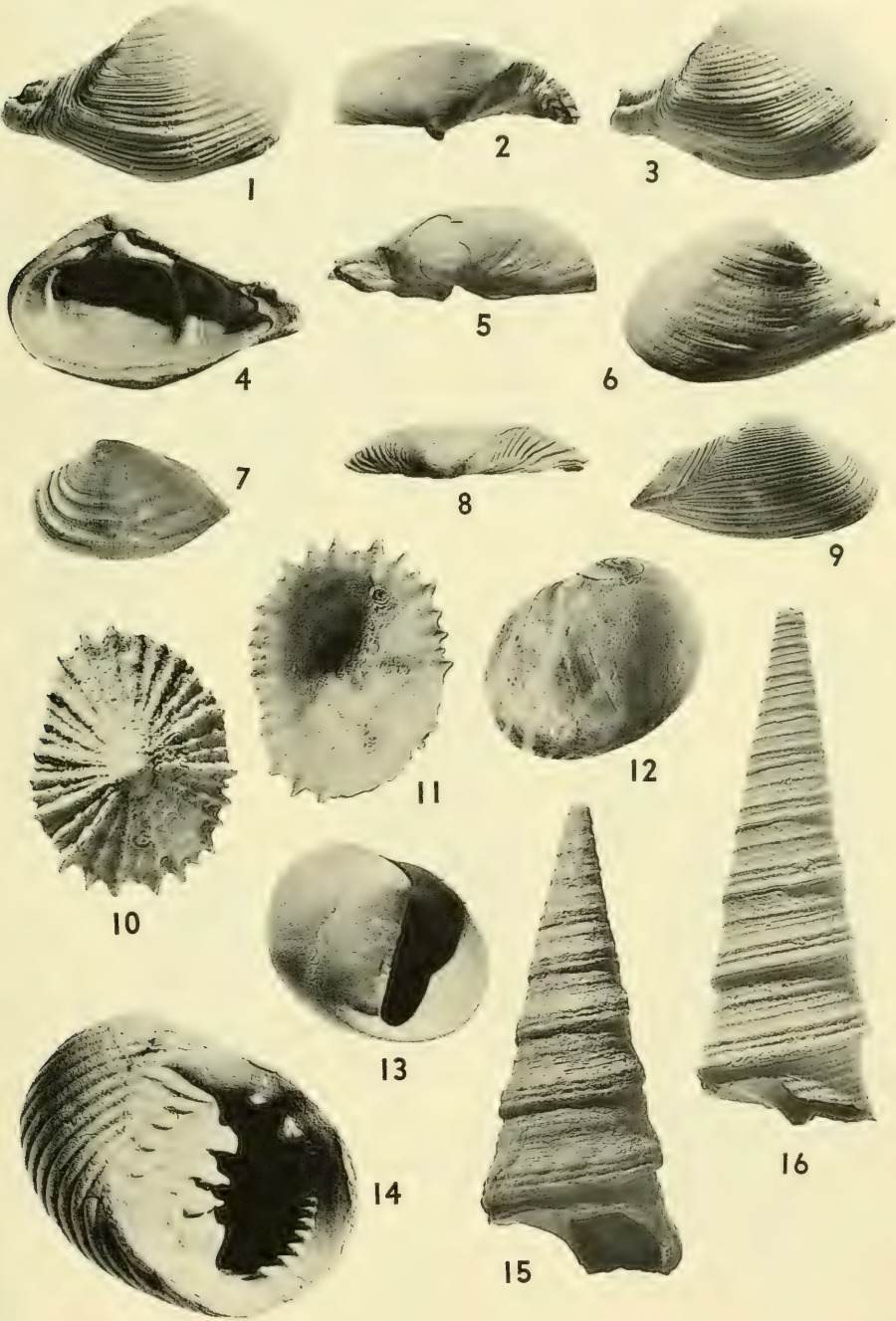


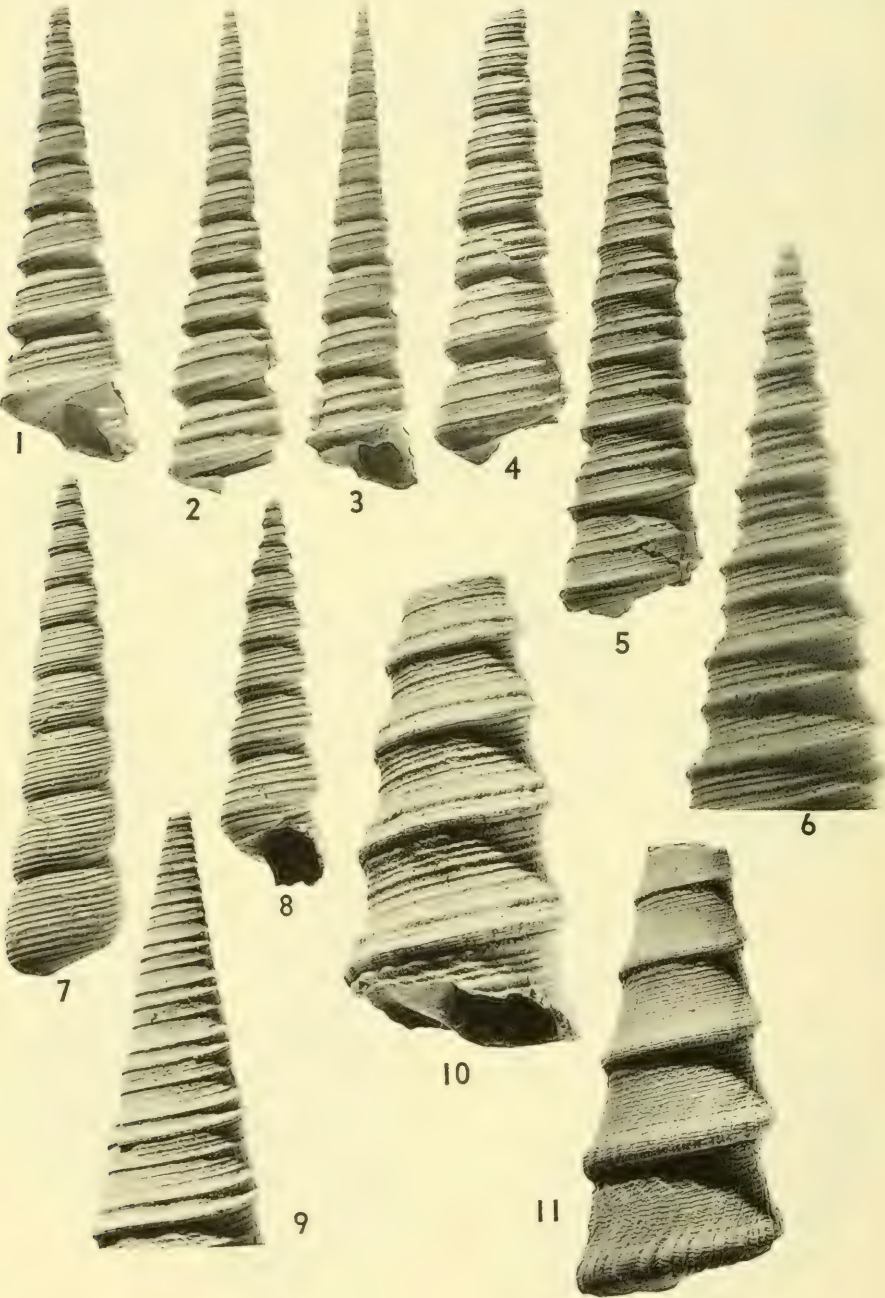
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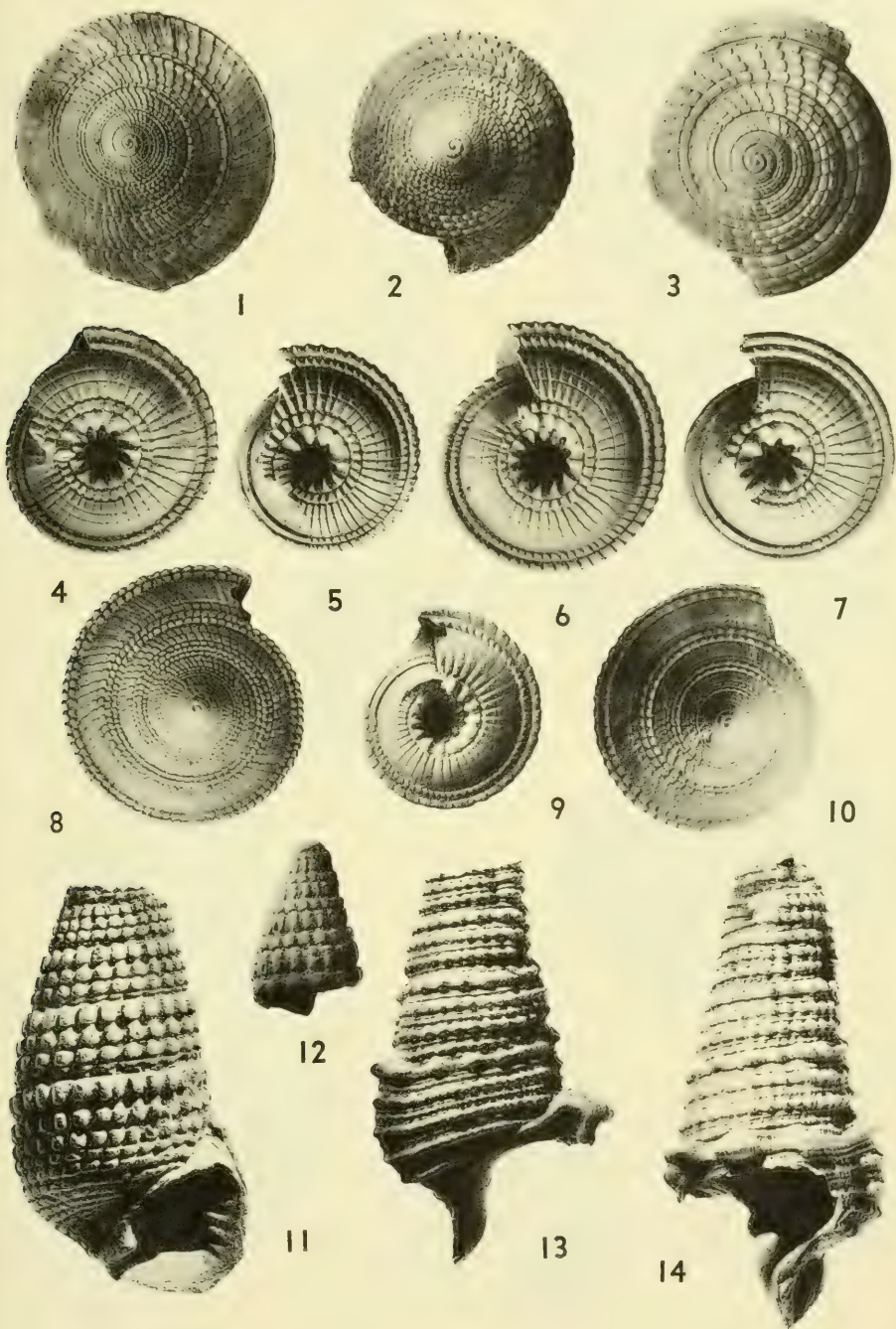


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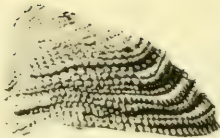
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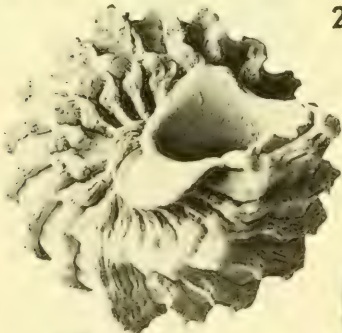
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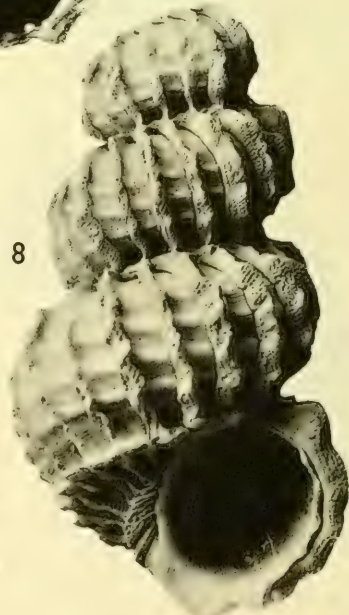
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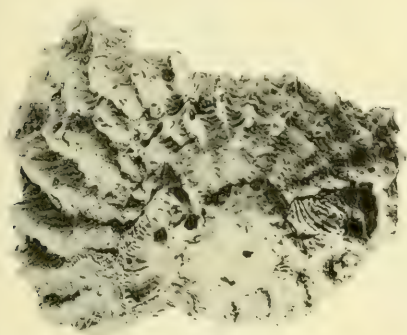
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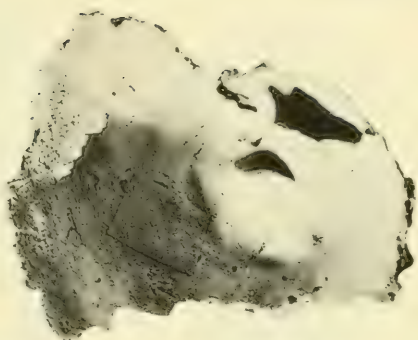
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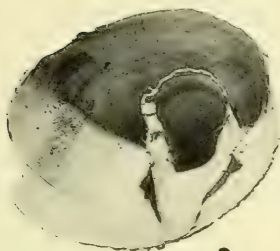
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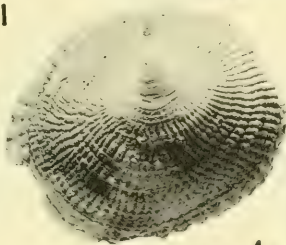
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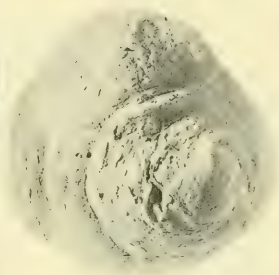
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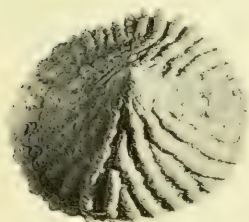
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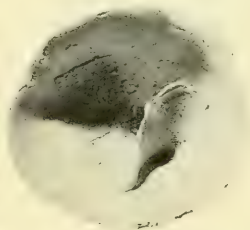
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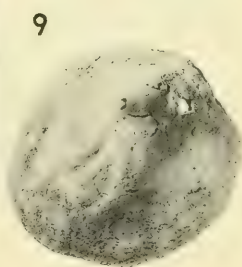
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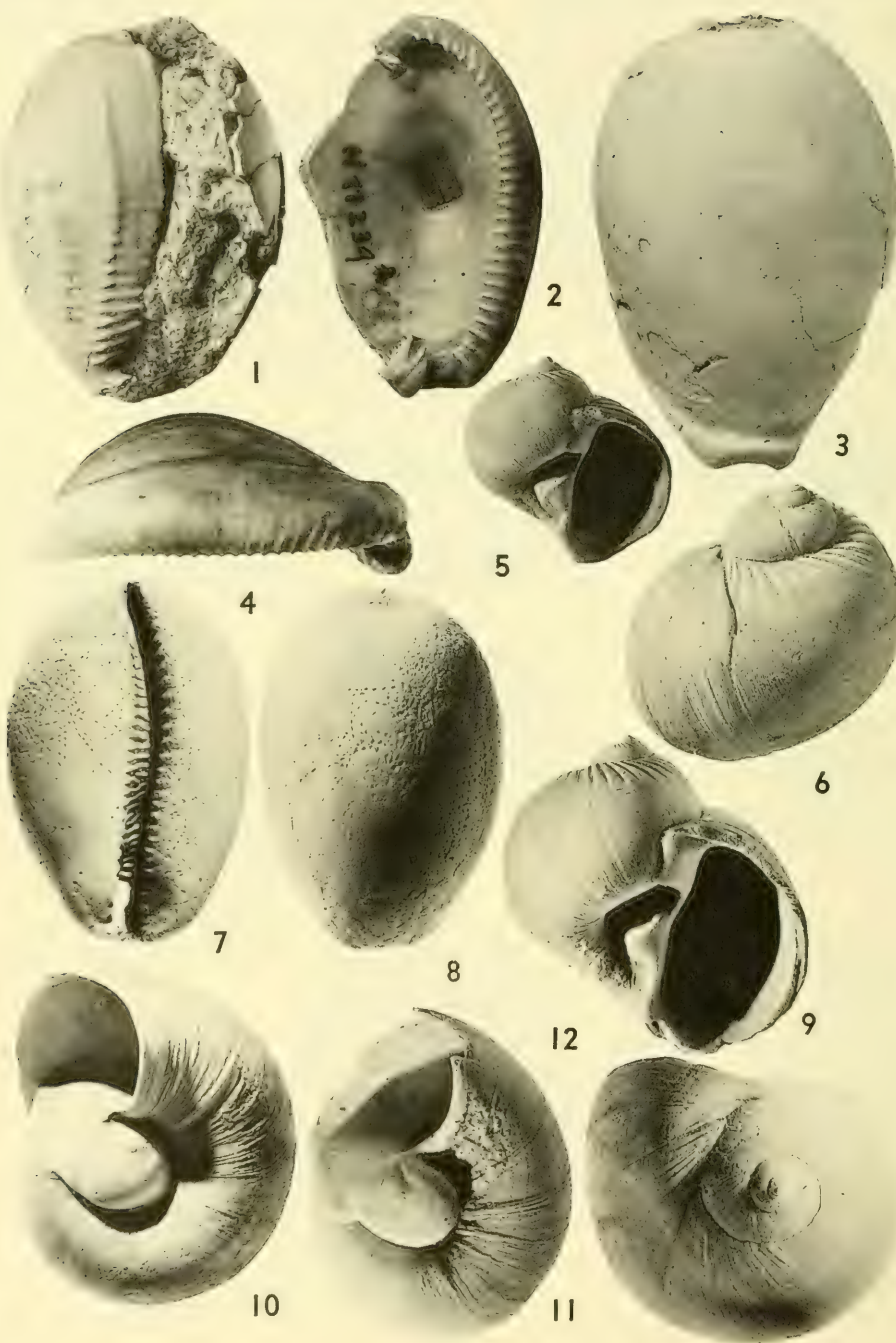
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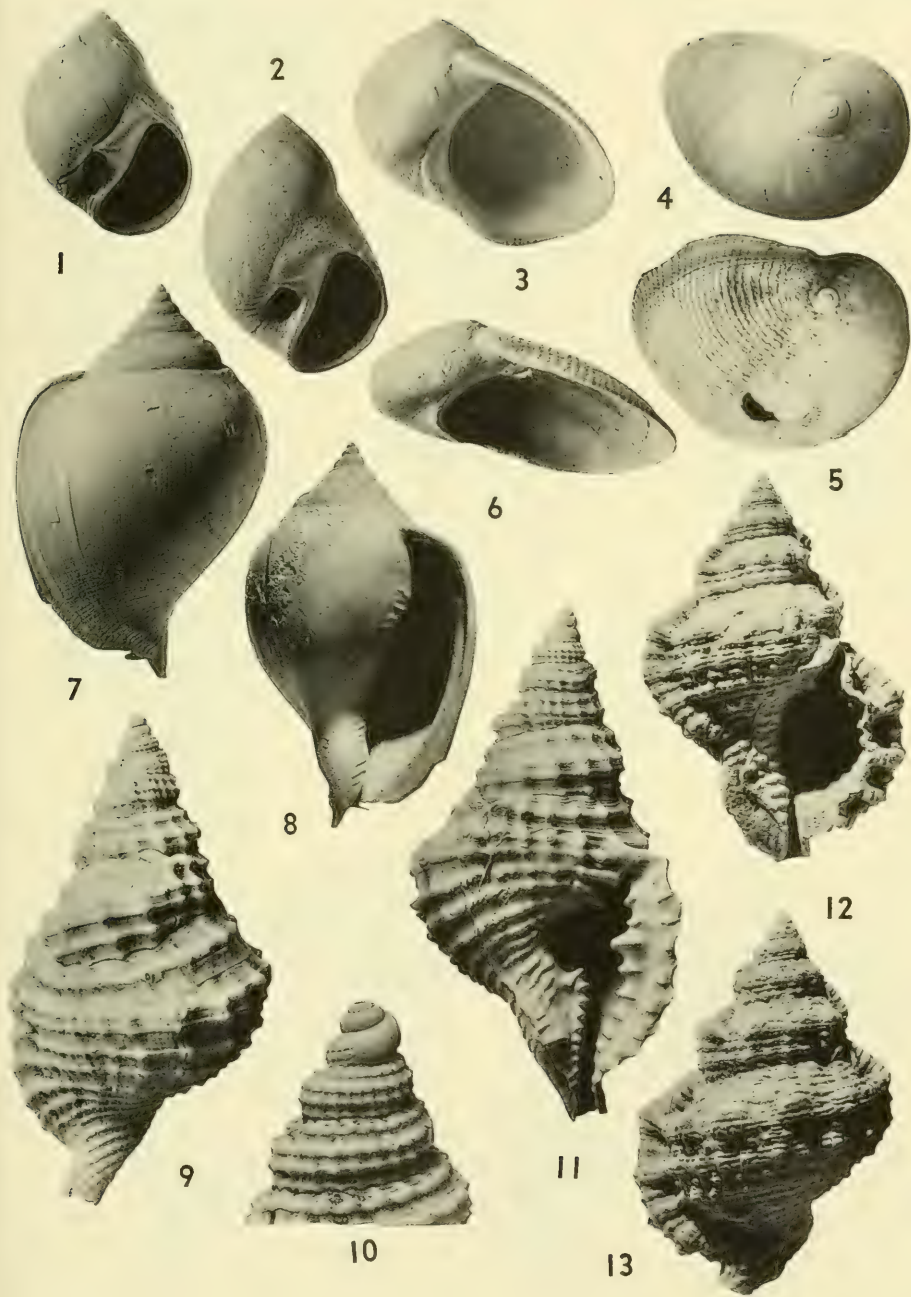


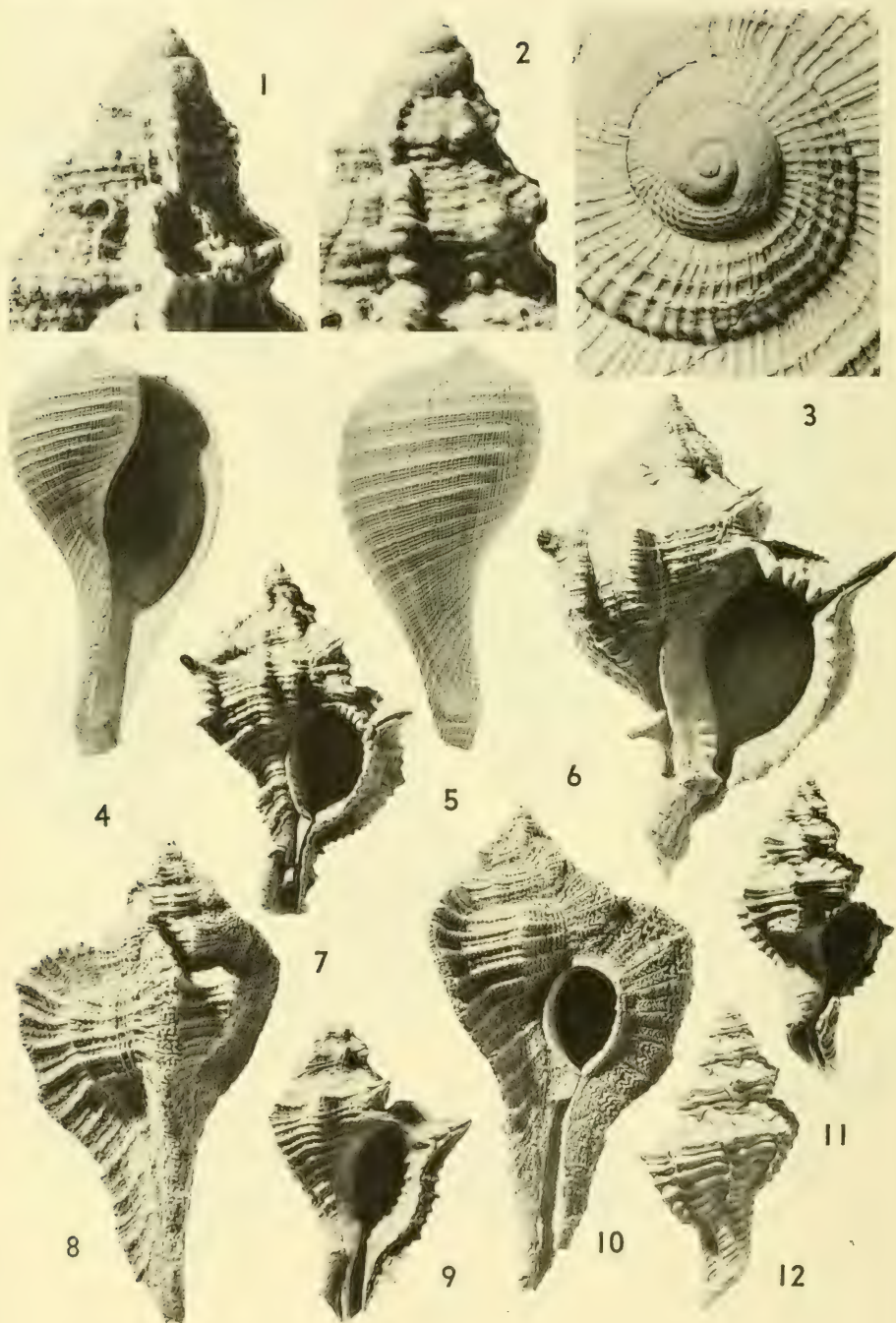
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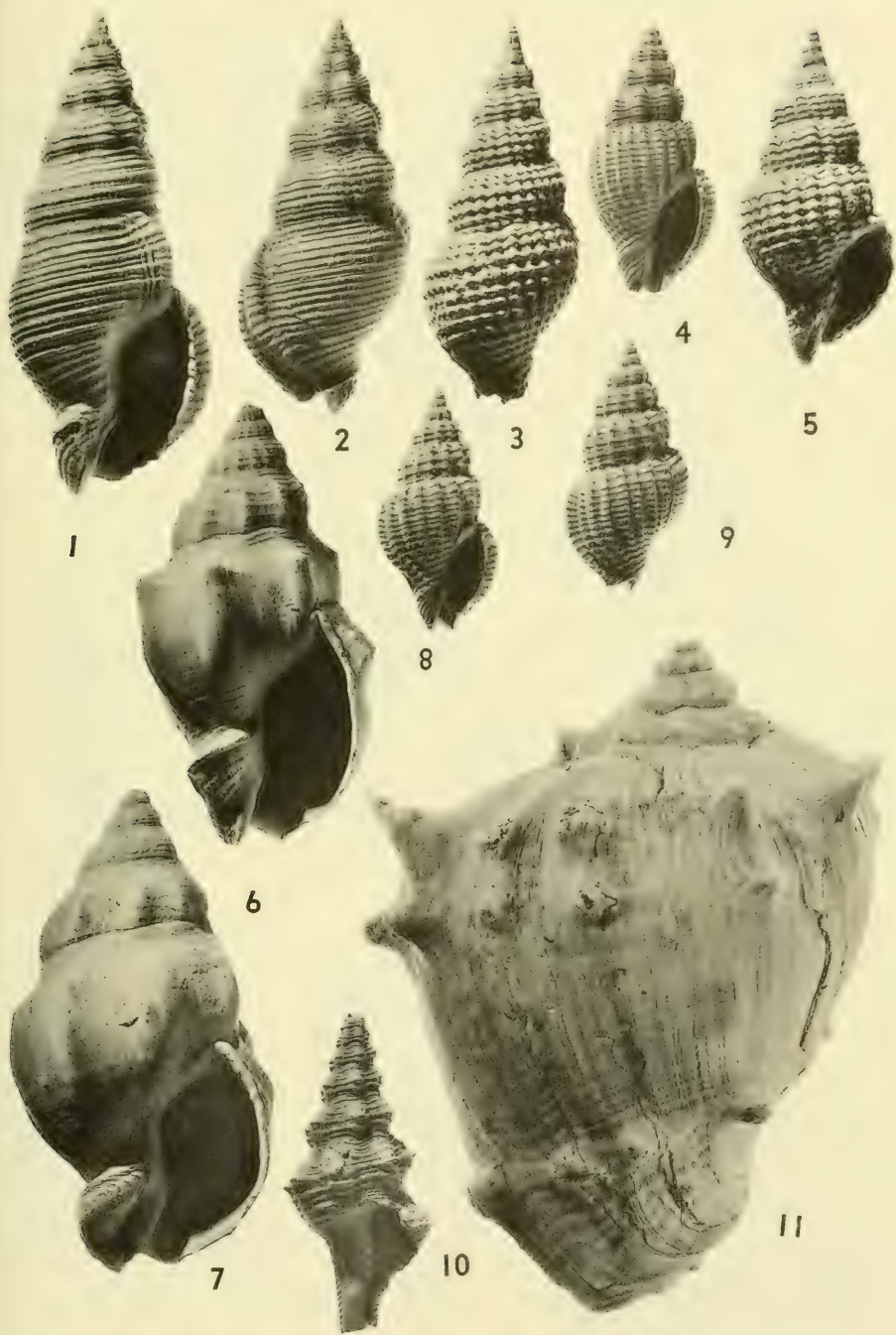


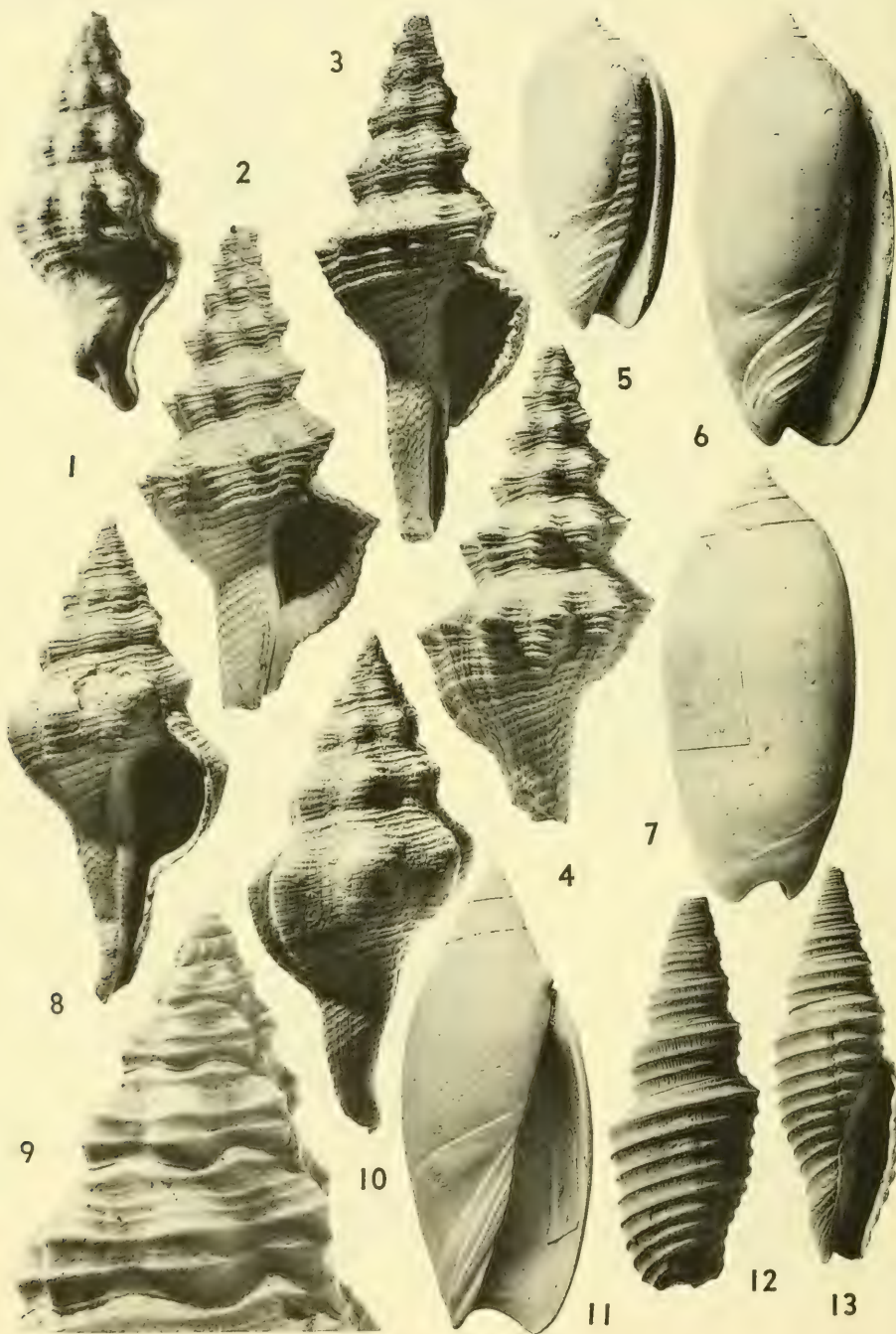
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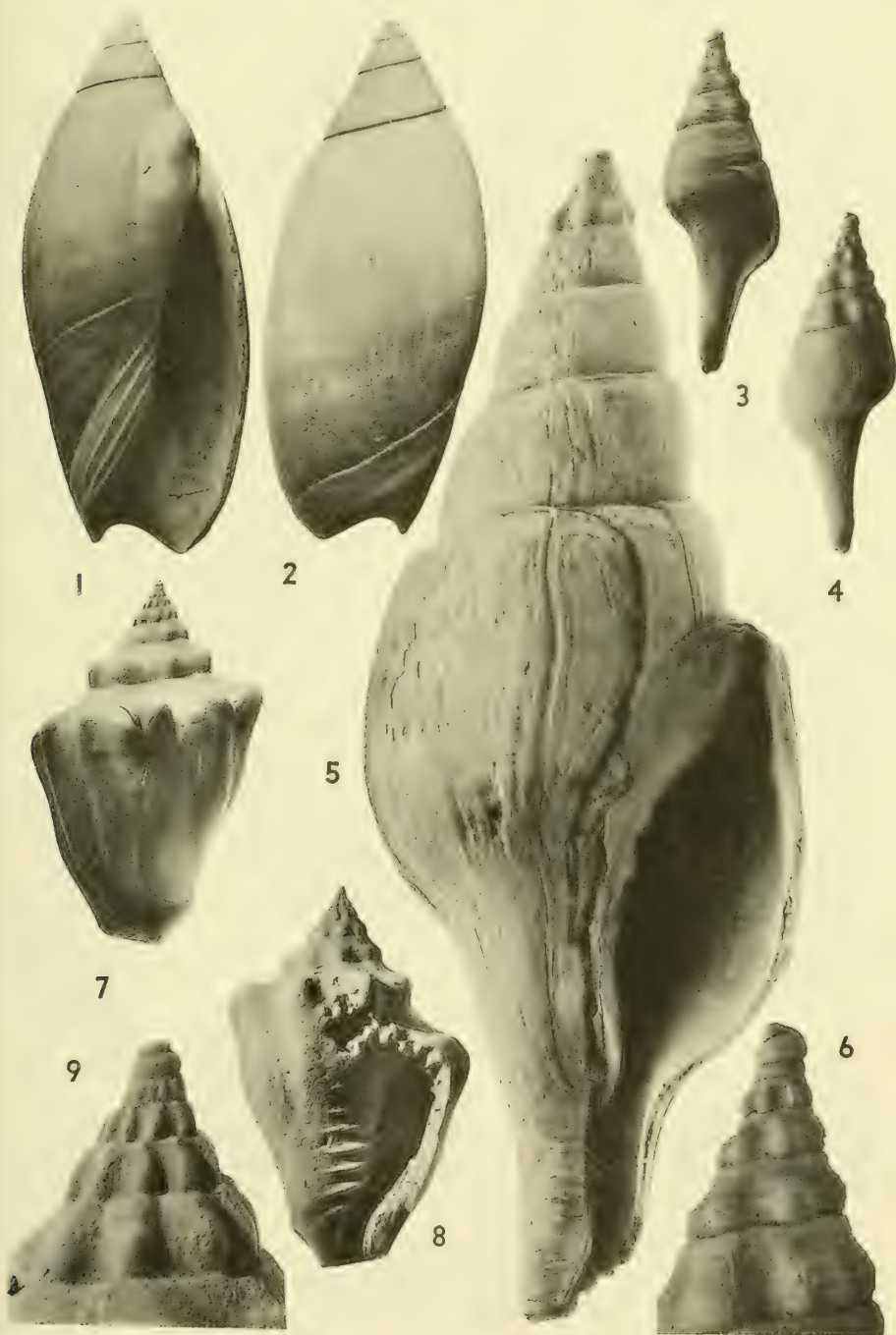


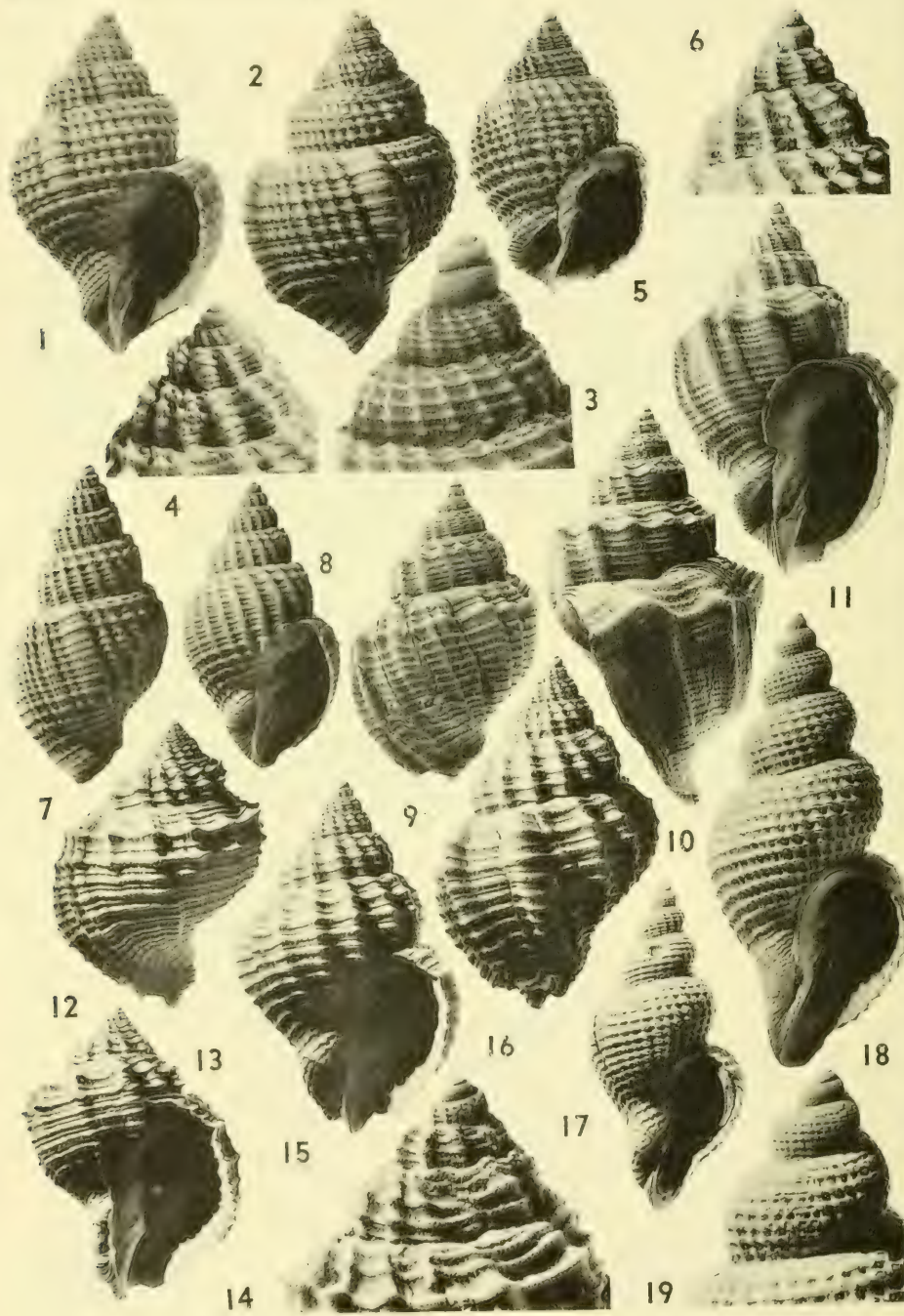
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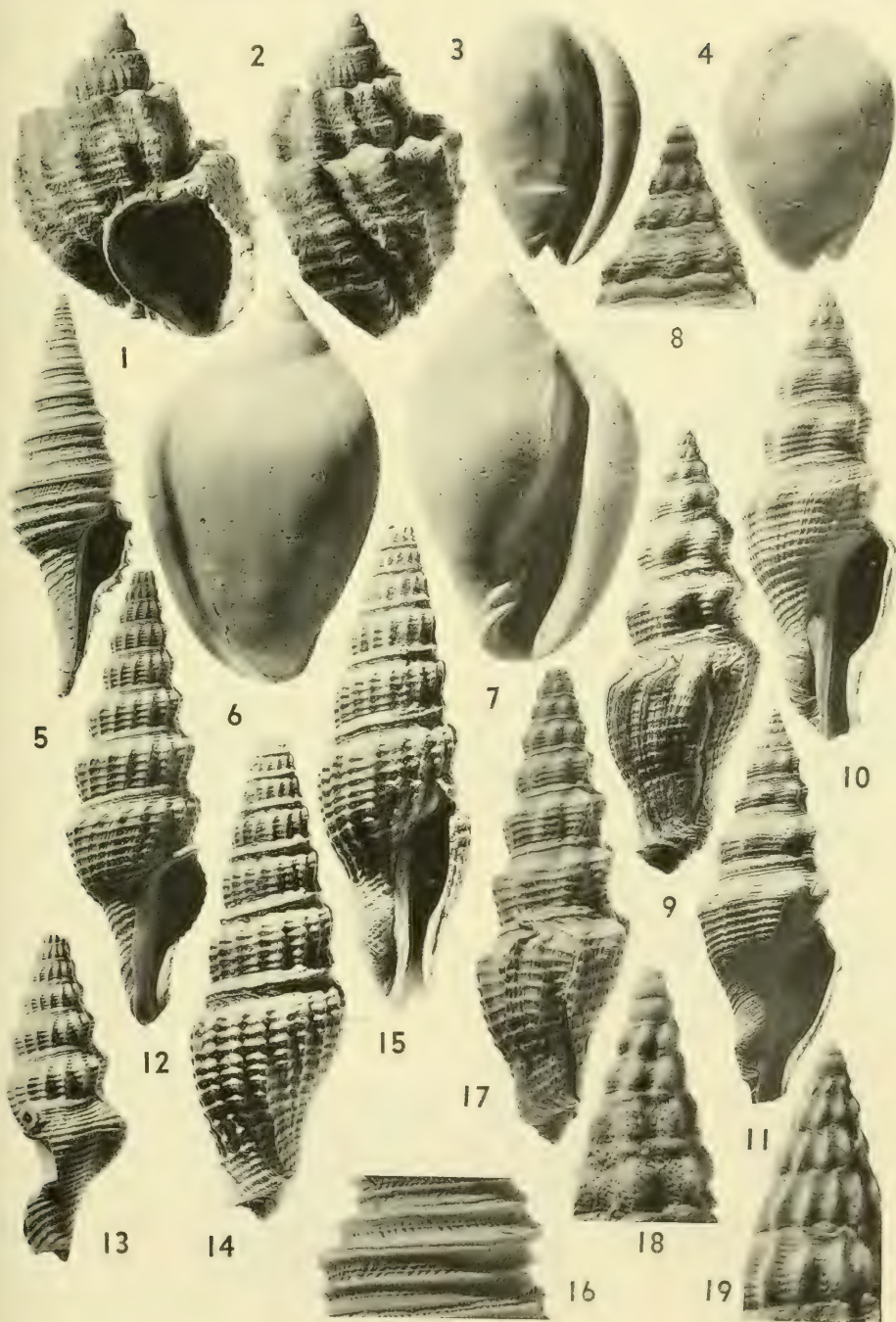


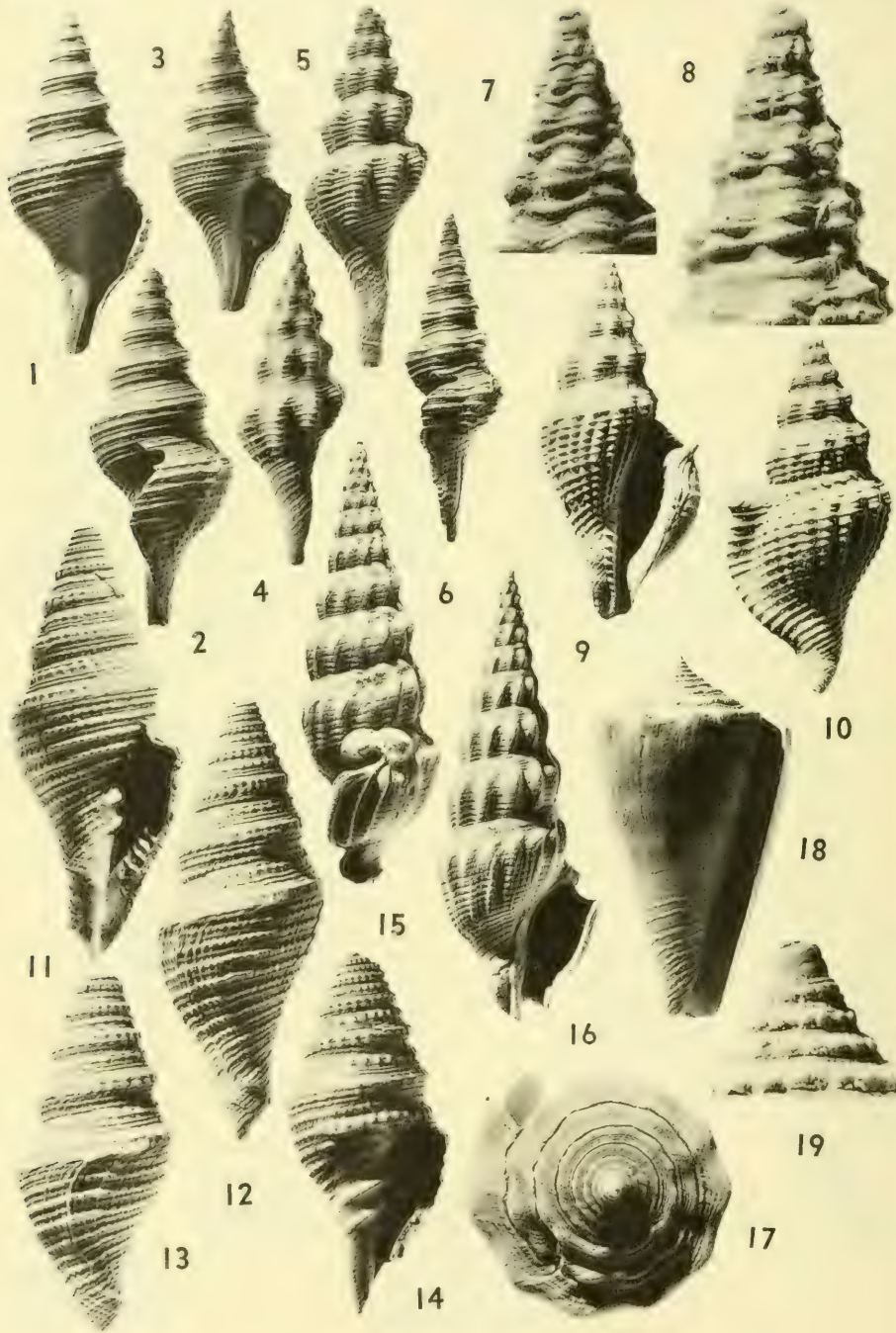
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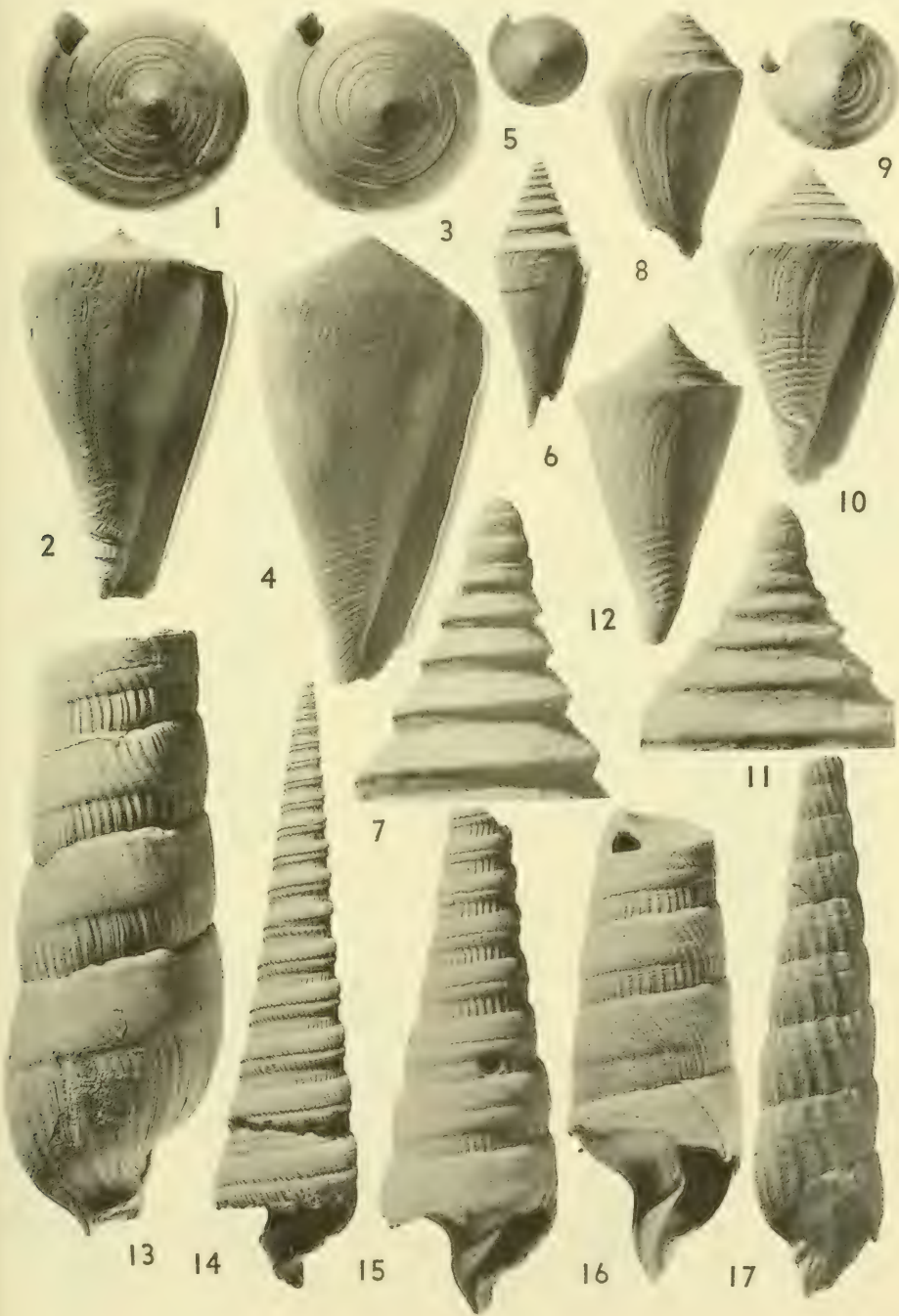


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**A REVIEW OF THE GENUS VOLUTA AND THE
DESCRIPTION OF A NEW SPECIES**

By

AXEL A. OLSSON

1965

**Paleontological Research Institution
Ithaca, New York, U.S.A.**

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A REVIEW OF THE GENUS *VOLUTA* AND THE DESCRIPTION OF A NEW SPECIES

AXEL A. OLSSON¹

INTRODUCTION

Voluta musica Linné, the type species of the genus *Voluta*, is a moderately common species at many localities in the southeastern Caribbean ranging as far north as Puerto Rico (Warmke and Abbott, 1961, p. 126). It is especially common along the coast of eastern Venezuela and its off-shore islands. Westward, it extends as far as the Goajira Peninsula, its distributional pattern like that of *Siphocypraea mus* and *Phyllonotus margaritensis*. As a Pleistocene fossil it has been recorded from Barbados, the Island of Aruba, and a few other places in the same general range. The city of Cumana in eastern Venezuela, opposite the pearl fisheries of Coche and Margarita Islands, was a favorite port of call for ships sailing between the Spanish Main and the Old World, and many of the more striking Caribbean shells reached Europe from this source. *Voluta musica* and its many varieties, because of its beauty and special markings recalling that of a musical notation, became a favorite amongst collectors, and hence we find it illustrated in most of the pre-Linnean works dealing with specimen shells and other curiosities of the sea.

During a visit with Mr. Simon Demarco of Fort Myers, Florida, I was shown an unusual *Voluta* which had been taken by shrimp trawlers off the coast of Texas. Although, the shell resembles both *V. musica* and *V. virescens* and on occasions had been identified with both, the form was clearly distinct. Because only three species of *Voluta* had been generally recognized in Caribbean waters, it became clear that a review of the whole genus was called for, especially one based on an examination of abundant original material contained in European museums. Illustrations of most of our Recent shells in the works of the older authors (Chemnitz, Lamarck [Encyclopédique], Kiener, Sowerby, and Reeve) are accurate to a high degree as to size, shape and color design, but the more fundamental characters of shell structure and sculpture upon which a Tertiary paleontologist generally relies are not so well shown. Several species of *Voluta* occur in the Miocene rocks of the Caribbean region (principally Costa Rica, Panama), but none so far have been recorded from the same age rocks on the Pacific side. These fossil species are the ancestors of the modern forms in the West Atlantic.

¹Honorary Research Associate, Smithsonian Institution; Research Associate, Paleontological Research Institution and of the Academy of Natural Sciences of Philadelphia.

The latest work on *Voluta* is that of Clench and Turner, 1964, the most comprehensive study of the genus so far. They recognized three species in the Recent American fauna; *Voluta musica* Linné, *V. ebraea* Linné, and *V. virescens* Lightfoot.

The author takes this occasion to thank the authorities of the various museums visited during the summer of 1964, and especially Messrs. Norman Tebble, Curator, and S. Peter Dance, Assistant in the Mollusca section of the British Museum (Natural History); and to Dr. Eugene Binder, Curator of Malacologie, Muséum d'Histoire naturelle in Geneva.

The holotype of *Voluta demarcoi*, n. sp. described herein is deposited in the U.S. National Museum, the paratype, at the Paleontological Research Institution at Ithaca, New York.

THE CARIBBEAN VOLUTES OF LAMARCK

Lamarck in his paper of 1811 in the *Annales du Muséum National d'Histoire naturelle* mentioned besides *Voluta musica* and *V. hebraea* of Linneaus, seven other forms of which two were classed as varieties of *V. musica*, the others described as full species. The originals or type specimens of these named forms are in the collections of the Muséum d'Histoire naturelle at Geneva, Switzerland, and through the cooperation of Dr. Eugene Binder, in charge of the Mollusca Division, the writer was able to study and photograph the specimens, a part of the photographs reproduced in this paper. The principal named forms, such as *V. thiarella*, *V. laevigata*, *V. carneolata*, *V. polyzonalis*, and *V. fulva* were accurately figured in the *Tableau Encyclopédique et Méthodique*. These illustrations agree well with the specimens as to size, shape, color design, and other characters. To *V. guinaica*, Lamarck gave reference to Chemnitz, 1785, but because the type is available, the Chemnitz figure is unimportant. In 1822, in the *Histoire naturelle des Animaux sans vertèbres*, Lamarck added *V. nodulosa* which on examination proved to be a worn specimen of *V. musica*. *V. carneolata* is a valid species distinguished easily from *V. musica* by its sculpture of strong, spiral cords, shape, and color design. *V. polyzonalis* is *V. virescens* Lightfoot, while *V. fulva* is a worn specimen of *V. virescens* similar to specimens from Payarde, near Colon, Panama. Kiener, who closely followed Lamarck and had access to his specimens, accepted Lamarck's specific names and refigured the shells in color with great accuracy, while Clench and Turner referred the Lamarckian species to the synonymy of either *V. musica* or *V. virescens*.

SUMMARY

The following arrangement of the Caribbean Recent species is suggested.

***Voluta musica* Linné**

Voluta musica Linné Pl. 80, figs. 2, 2a
Lamarck, Annales, 1811, p. 391; Encycl., III, pl. 380, figs. 1a, b. The typical form with angled shoulder and shoulder nodes

Voluta thiarella Lamarck Pl. 81, fig. 5; Pl. 82, figs. 2, 2a
Annales, 1811, p. 392; Encycl., III, pl. 380, figs. 3a, b. A high-spired form with shoulder and shoulder nodes.

Voluta laevigata Lamarck
Annales, 1811, p. 67; Encycl., III, pl. 379, figs. 2a, b.

A *V. musica* with rounded shoulder and no nodes.

Voluta guineaica Lamarck Pl. 80, fig. 4
Annales, 1811, p. 393. A dark-colored *V. musica*.

Voluta nodulosa Lamarck Pl. 80, fig. 5
Animaux sans Vertèbres, 1822, p. 342. A worn specimen of *V. musica*.

There are five specimens of *Voluta musica* in the Linnean collection in London and of which two are herein figured. A specimen marked with the number 370 corresponding to the numeration in the Systema may be selected as the lectotype. This is a small shell (Pl. 80, fig. 1) with a strongly noded shoulder and the usual color design associated with the species; this specimen has nine simple plaits and a height of 38 mm. The other four specimens measure.—No. 2, height 58.3 mm.; No. 3, height 55.3 mm.; No. 4, height 50.9 mm. (Pl. 80, fig. 1a); No. 5, height 4.41 mm. There seems to be no reason to question the authenticity of these specimens and that one or all of them were not in Linneaus' hands when he wrote the Systema (as questioned by Clench and Turner, 1964, p. 142).

The type specimen of *V. thiarella* at Geneva agrees well with the figure in the Encyclopédique as to size, shape, and color pattern. Its general color is pale brown, its markings of darker shade. The surface is smooth except for obscure spirals on the sutural collar. Columella with ten plaits, the five lower ones strongest. The specimen measures:—Length 67.2 mm., diameter 37.5 mm.

Voluta musica is a variable shell as far as height of spire, strength or absence of a shoulder, strength of the shoulder nodes, but the other

characters remain constant such as the smoothness of surface, shape of aperture, columellar plaits, and the design of the color pattern. The nuclear whorls are trochoid and fairly large, set between distinct sutures. The species is common at favorable stations, especially along the north coast of Venezuela, and some of its off-shore islands such as Margarita and Coche near Cumana. Being such a common and beautiful shell, it reached Europe early and in numbers, and it has been well figured in most of the earlier works.

Range.—The southeastern Caribbean, westward along the Venezuelan coast probably to the Goajira Peninsula, and northward through the Lesser Antilles to the Dominican Republic and Puerto Rico.

***Voluta musica plicata* Dillwyn**

Pl. 81, figs. 4, 4a

Voluta plicata Dillwyn, 1817, Descriptive Catalogue of Recent Shells, vol. 1, No. 152, p. 563.

Voluta sulcata Lamarck, 1811, Ann. Mus. d'Hist. nat., Paris, 17, p. 68; reference Chemnitz, 1788, vol. X, p. 151, t. 149, figs. 1403, 1404.

There are specimens in the U. S. National Museum collection, USNM, No. 414049, Guadaloupe, Webb, which agree reasonably well with Chemnitz' type figure.

In the photographed specimen; the nucleus is large, like *V. musica*, the whorls weakly shouldered and bearing low axial nodes fading out below, the surface closely overrun by low, spiral cords. The pillar has nine, long, primary plaits, weaker below. The color design is like that of *V. musica* but differs in small details.

Specimen figured, length 54.2 mm., diameter 29.7 mm.

Another specimen measures.—Length 72 mm., diameter 39.5 mm.

Although the surface is sculptured with spiral cords, it seems best to regard this form as a subspecies of *V. musica* pending more detailed information.

***Voluta carneolata* Lamarck**

Pl. 80, figs. 3, 3a; Pl. 83, fig. 7

Voluta carneolata Lamarck, 1811, Ann. Mus. d'Hist. nat., Paris, 17 p. 393; Encycl., III, pl. 379, on figs. 4a, b; Lamarck, 1822, Animaux sans vertèbres, p. 341, sp. 25.

The type specimen at Geneva shows strong spiral cords in the sutural zone and around the base. The color is a delicate, creamy rose, the markings in a rich brown. The inner lip has 10 plaits, heaviest below, weakening above. The protoconch is large, like that of *V. musica*.

Length 49 mm., diameter 38.2 mm. Type.

Same distributional range as *V. musica*.

***Voluta polypleura* H. Crosse**

Pl. 81, figs. 3, 3a

Voluta musica polypleura Crosse, 1876, Jour. de Conchy., vol. 24, pp. 163-166, pl. 5, fig. 6 (loc. unknown).

1. Au point de vue de la coloration, l'absence complète des linéoles transverses, également espacées et imitant assez exactement des portées de musique, qui caractérisent habituellement l'espèce;
2. Au même point de vue, l'absence de taches noires sur le bord externe du péristome;
3. La présence de nombreuses costulations occupant l'espace compris entre les grosses côtes longitudinales qui forment la continuation des tubercules;
4. L'existence, dans la région suturale des tours, de plusieurs sillons fortement prononcés.

Habite?

This volute is known to me only by its figure, but its pattern is so different from all other members of the genus that it can be accepted for the present as a distinct species. The type is probably in the Paris museum.

***Voluta virescens* Lightfoot**

Pl. 80, figs. 6, 6a, 7, 7a; Pl. 81, figs. 1, 1a, 6; Pl. 82, figs. 5, 6; Pl. 83, figs. 1, 1a, 6, 6a.

Voluta virescens Lightfoot, 1786, Catal. Portland Museum, 26, pp. 136, 174 reference to Martini, 1777, Conchylien-Cabinet (1) 3, p. 97, figs. 932, 933; Reeve, 1849, Conch. Icon., vol. 6, pl. 9, fig. 19.*Voluta polyzonalis* Lamarck, 1811, Ann. Mus. d'Hist. nat., Paris, 17, p. 68 reference to Encyclopédique et Methodique, 3, pl. 379, figs. 1a, b; Kiener, 1839, Icon. des Coquilles vivantes, vol. 3, *Voluta*, p. 32, pl. 32, fig. 1, fig. 2 (var); Sowerby, G. B. I., 1845, Thes. Conchyl., vol. 1, p. 212, No. 46, pl. 52, figs. 77, 78.*Voluta fulva* Lamarck, 1811, Ann. Mus. d'Hist. nat., Paris 17, p. 68, reference to Encycl. Method., 3, pl. 382, on figs. 3a, b.*Voluta ? virescens* Solander, Clench and Turner, 1964, Johnsonia, vol. 4, No. 43, p. 146, pls. 82, 84.

Shell small or medium size, relatively solid with a conic spire of four or more whorls rising about one-third the full length of shell. The body whorl is reverse conic, generally with an angled shoulder, noded by about 12, short, axial riblets, the whole surface covered by raised spiral threads set fairly wide apart and generally weakly beaded by growthline ridges. Color varies according to the freshness of the shell from a dark brown to a pale cream, the lighter colored forms show a sparse sprinkling of small brown dots and some larger ones.

A radular ribbon extracted from a shell in the McGinty collection (Florida), measures 38.5 mm. in length. Locality indefinite, probably from off the coast of Texas.

The ribbon is small, with about 62 closely packed rachidian teeth, the length of ribbon about 1.40 mm., and a width of .20 mm. The general pattern is similar to that of *V. musica* and *V. ebraea* but differs in detail. The end cusps are large, broadly triangular in shape, the intermediary one smaller and divided into sets of primary, secondary, and tertiary size, their individual shape variable.

Voluta virescens is a relatively rare species in most museum collections and some uncertainty remains as to its full characters and range of variation. The species is fairly common at a few places along the Caribbean coast of Panama, especially in the vicinity of Colon, Payarde, where it is found mainly as shells cast up on the beach or from fill material dredged or pumped up from nearby waters. These Panama shells are relatively small, often with a greenish cast, the color depending upon their freshness. The larger specimens seen in many European museums (without definite locality citations) are more strongly colored and may possibly have come from other parts of the Caribbean region. The beautiful colored figures of Kiener (pl. 32, figs. 1, 2) and of Sowerby (*Thesaurus Conchyl.*, 1, pl. 52, figs. 77, 78) show shells of this kind.

A specimen of *V. polyzonalis* at the Muséum d'Histoire naturelle at Geneva marked "type" (Pl. 81, figs. 1, 1a) has large shoulder nodes and measures; height 58.8 mm., diameter 33.2 mm. Another specimen in the same lot (Pl. 80, figs. 7, 7a) has smaller shoulder nodes and measures; height 60.4 mm., diameter 31.7 mm. The type of *V. fulva* is a medium-sized shell apparently beach worn with small nucleus and strong, spiral sculpture. Color pattern is formed by narrow white strips between wide brown bands, it measures—height 45.8 mm., diameter 26.7 mm. This specimens agrees well with worn specimens of *V. virescens* from Panama.

***Voluta demarcoi*, new species** Pl. 81, figs. 7, 7a; Pl. 82, figs. 1, 1a, 1b, 1c

The shell is medium or large size, ovate, solid, with an elevated spire of about six whorls (including the nuclear ones) about half the length of the aperture. The protoconch is relatively large, bulbous or cap-shaped, composed of about $1\frac{1}{2}$ turns, and in the type specimens colored a pale rosy brown. All whorls have rounded shoulders, and on the body whorl, the shoulder is placed high, opposite to the end of the aperture; on the whorls of the spire, the shoulder lies a little above the middle. The body whorl is large, subelliptical, forms most of the surface, and is only a little longer than the length of the aperture, its shoulder bearing about eight, low

nodes which fade-out below. There are similar shoulder nodes on all the whorls of the spire and appear larger as they undulate the whole visible surface. Suture are widely appressed, the zone sculptured with coarse, spiral cords. In addition to the shoulder nodes, the surface of the body whorl is covered with smaller axials or longitudinal ridges resembling enlarged, crowded growth lines. Coarse spiral threads cover the sutural zone and around the base of the body whorl. The spirals are particularly strong on the whorls of the spire, encroaching lower as to cover the shoulder nodes as well. The aperture is elongate, the outer lip thickened in the adult, its margin within smooth. A series of long lirae or plaits (about 14) cover the length of the inner lip, the two lowest being the strongest, narrower and weaker above, some with a tendency of alternating in size. There is a spread of callus over the parietal wall outward. The base color is a mellow rose or pinkish brown, overlain by a zoned pattern of large, brown blotches crisscrossed by brown lines and small brown spots. The anterior canal is short, encircled by a large folded fasciole terminating in a wide, siphonal canal notch bordered by a raised edge.

Length 84.6 mm., diameter 42 mm. Holotype, 637275 USNM.

Length 79 mm., diameter 34.5 mm. Paratype, No. 6081 PRI.

This fine species is named for Mr. Simon Demarco, well known for his fine collection of world-wide shells at his museum (The Florida Marine Museum) at Fort Myers, Florida.

Specimens collected by shrimp trawlers about 105 miles off Mesquital, Texas, in 100 fathoms. Another specimen in the collection of the U.S. National Museum; Punta Patuca, 5 fm. (mud) Honduras (Steger); Dr. R. L. Alsaker collection, No. 631847 USNM.

FOSSIL SPECIES

***Voluta alfaroi* Dall**

Pl. 82, fig. 4; Pl. 83, figs. 4, 4a

Voluta musica Gabb, 1881, Description of Caribbean Miocene Fossils. Acad. Nat. Sci. Philadelphia, Jour. 2d ser. vol. 8, p. 355 (not of Linné, probably *V. alfaroi*).

Voluta alfaroi Dall, 1912, Smith. Misc. Coll., vol. 59, No. 2, p. 8 Sta. 5882i. Costa Rica. MacDonald; Olsson, 1922, Bull. Amer. Paleont., vol. 9, No. 37, p. 271, pl. 11, fig. 2; Dall, 1925, U. S. N. Museum, Proc., vol. 66, Art. 17, p. 30, pl. 17, fig. 2.

Shell small or medium size, with a large, shouldered body whorl and a high, conic spire. Whorls shouldered bearing short nodes on all whorls

which in some specimens become obsolete on the back of the body whorl, the shoulder then rounded and less well defined. Aside from the shoulder nodes, the surface is smooth except for a zone of spirals around the anterior canal. Columellar plaits numerous, alternating in size below, more uniform and smaller above. Protoconch as illustrated.

On the type specimen (USNM, No. 214347, Banana River, Costa Rica), the spire whorls preceding the penultimate are crossed by five or six, widely spaced, faint, incised lines which represent nearly obsolete spiral cords, and other specimens in the type lot show the same character. Stronger, coarser spirals encircle the base and anterior end of the shell, but otherwise, the general surface is essentially smooth. The pillar wall has five primary plaits with one or more accessory ones between. The nucleus is of medium size. The holotype measures.—Length 50.7 mm., diameter 27 mm.

The largest specimen in the collection from the Banana River, measures.—Length 65.9 mm., diameter 35 mm.

Middle Miocene. Gatun. Banana River, Costa Rica; Water Cay, Chiriqui Lagoon, Panama.

***Voluta eurytera* Woodring**

Pl. 83, fig. 5

Voluta alfaroi eurytera Woodring, 1964, U. S. Geol. Sur., Prof. Paper, 306-C, pp. 287, 288, pl. 45, figs. 14, 18, 19. Late Miocene. Panama, near Canal Zone.

This is a top-shaped, broadly shouldered form with a medium height conic spire, with closely appressed sutures undulated by the shoulder nodes and apical whorls tipped by a small, narrow, cylindrical protoconch. The general surface is smooth except for lines of growth. Columella with five or six plaits. The siphonal canal notch is deep, developing a small fasciole edged by a low keel.

Length 48 mm., diameter 30.5 mm. Type, USNM 643691.

One specimen shows faint traces of an original color pattern, but the shell has not been examined closer under ultra-violet light.

This shell is fully distant from *V. alfaroi* Dall, with which it was associated by Woodring, differing by its broad shoulder, short, conic spire with appressed sutures, and in several other respects. It is a late Miocene species found in the upper Gatun and in the Chagres beds in Panama, west of the Canal Zone.

***Voluta virescens* Lightfoot**

Pl. 81, fig. 6; Pl. 82, fig. 5; Pl. 83, fig. 3

For synonymy see p. 661.

As fossil, *Voluta virescens* is common in the Limon formation of upper Miocene age at Puerto Limon, Costa Rica, and also in the same age rocks at Bocas del Toro, Panama. Specimens vary considerably in the coarseness of sculpture but are similar in most respect to examples of the Recent shell.

Genus FALSILYRIA Pilsbry and Olsson, 1954

Type species by original designation, *Lyria pycnopleura* Gardner. Lower Miocene of Florida.

Similar to *Voluta* in shape and parietal and columellar plaits but distinguished by the constricted ends of the axial riblets bordering the suture. Sculpture of axial riblets, smooth or crossed by encircling spirals. Two closely related species occur in the lower Miocene (Tampa and Chipola formations) of Florida.

***Falsilyria pycnopleura* (Gardner)**

Pl. 83, fig. 8

Lower Miocene, Chipola beds, Chipola River, C. R. Locklin collection.

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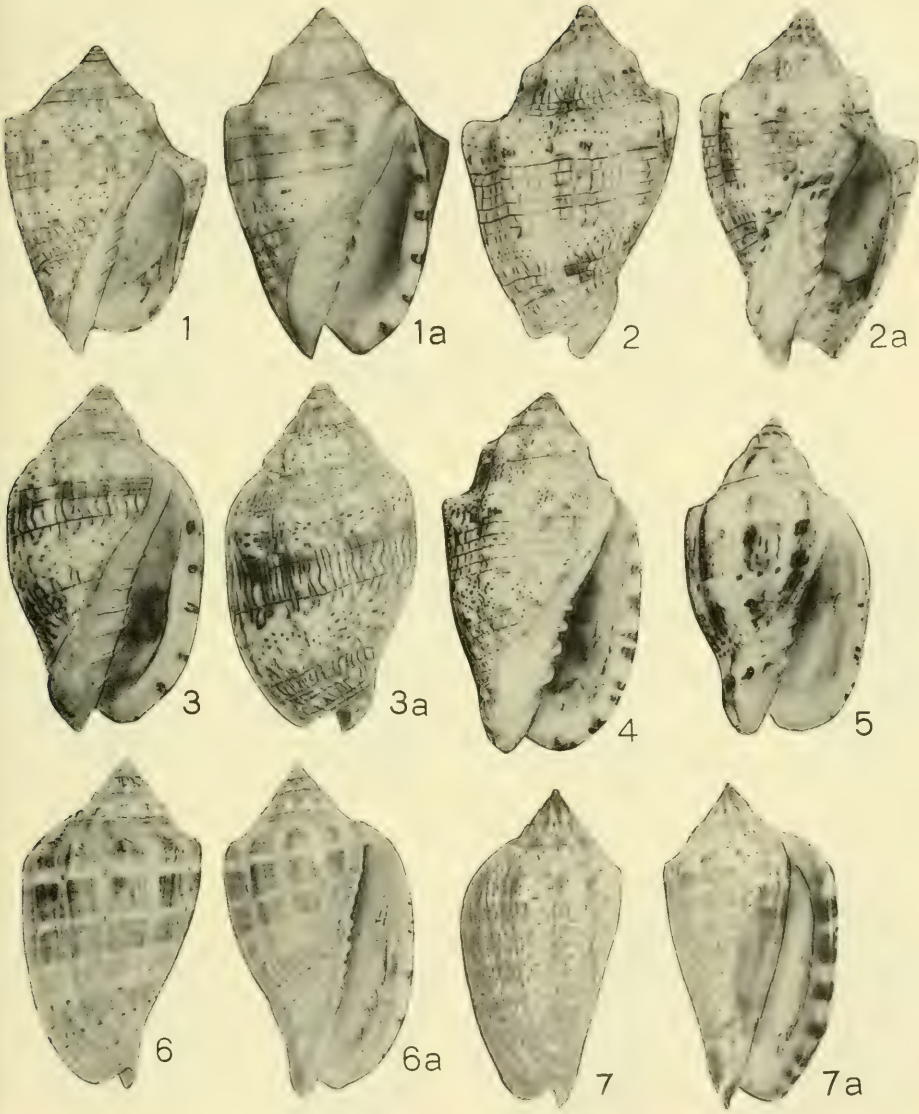
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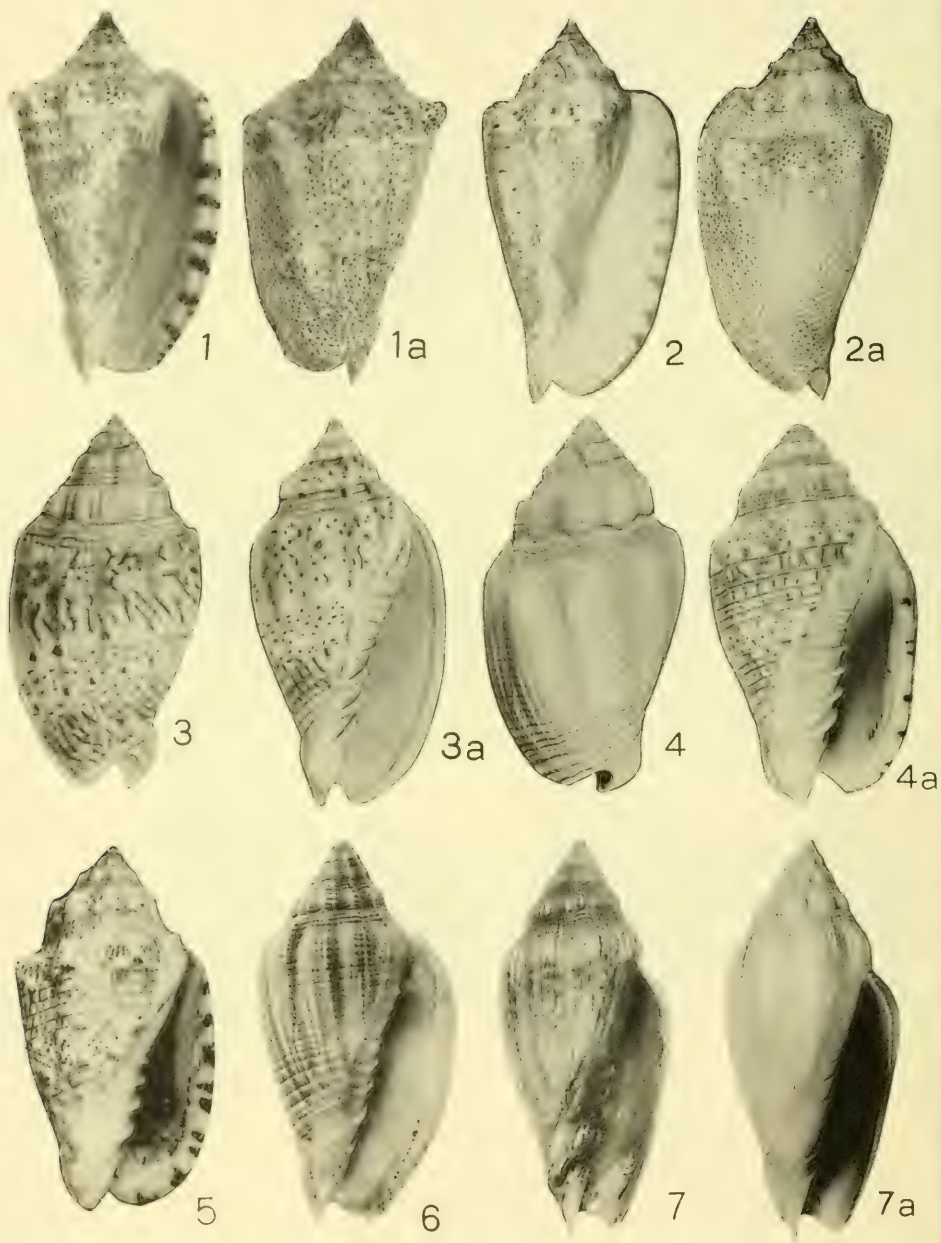
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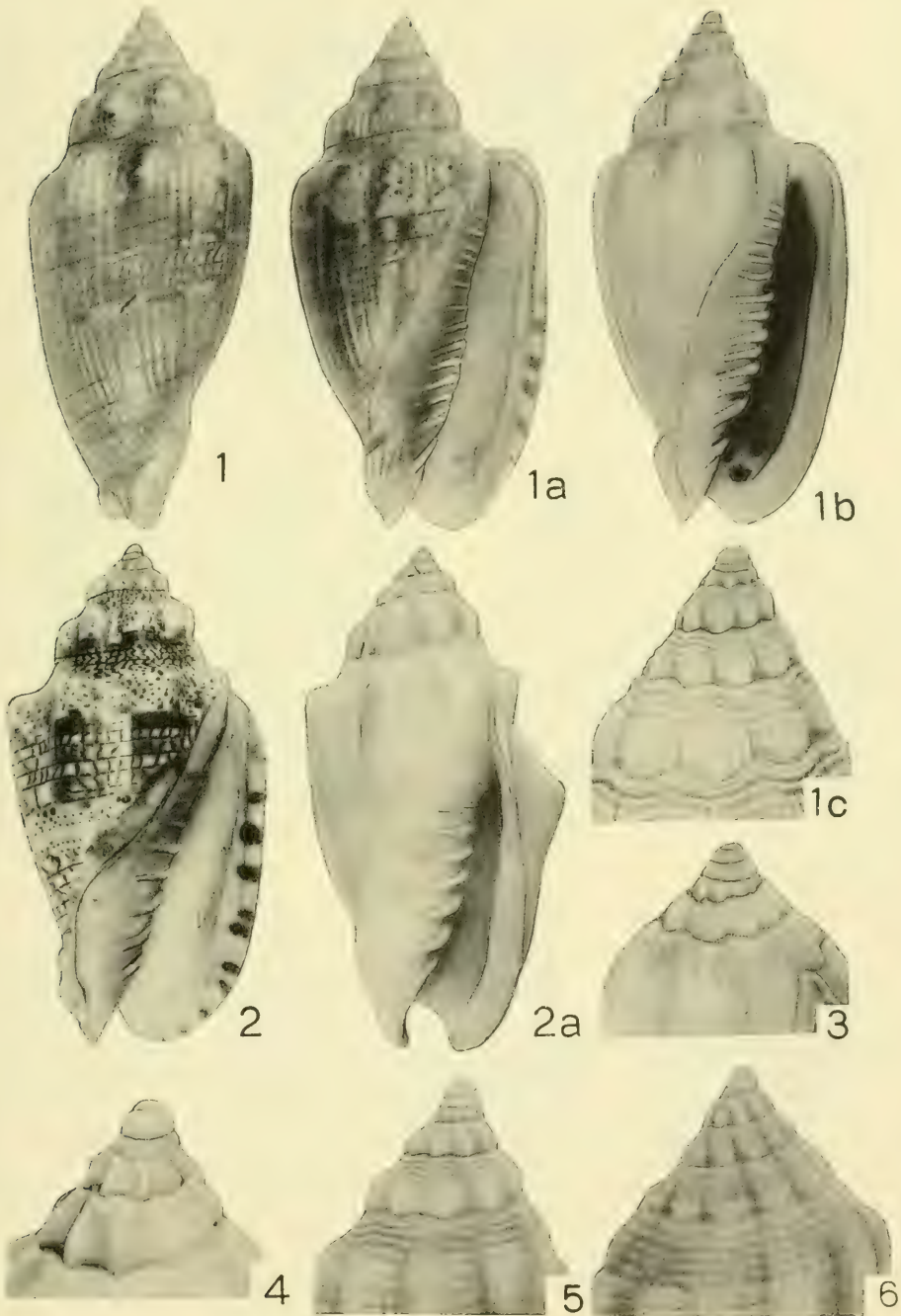


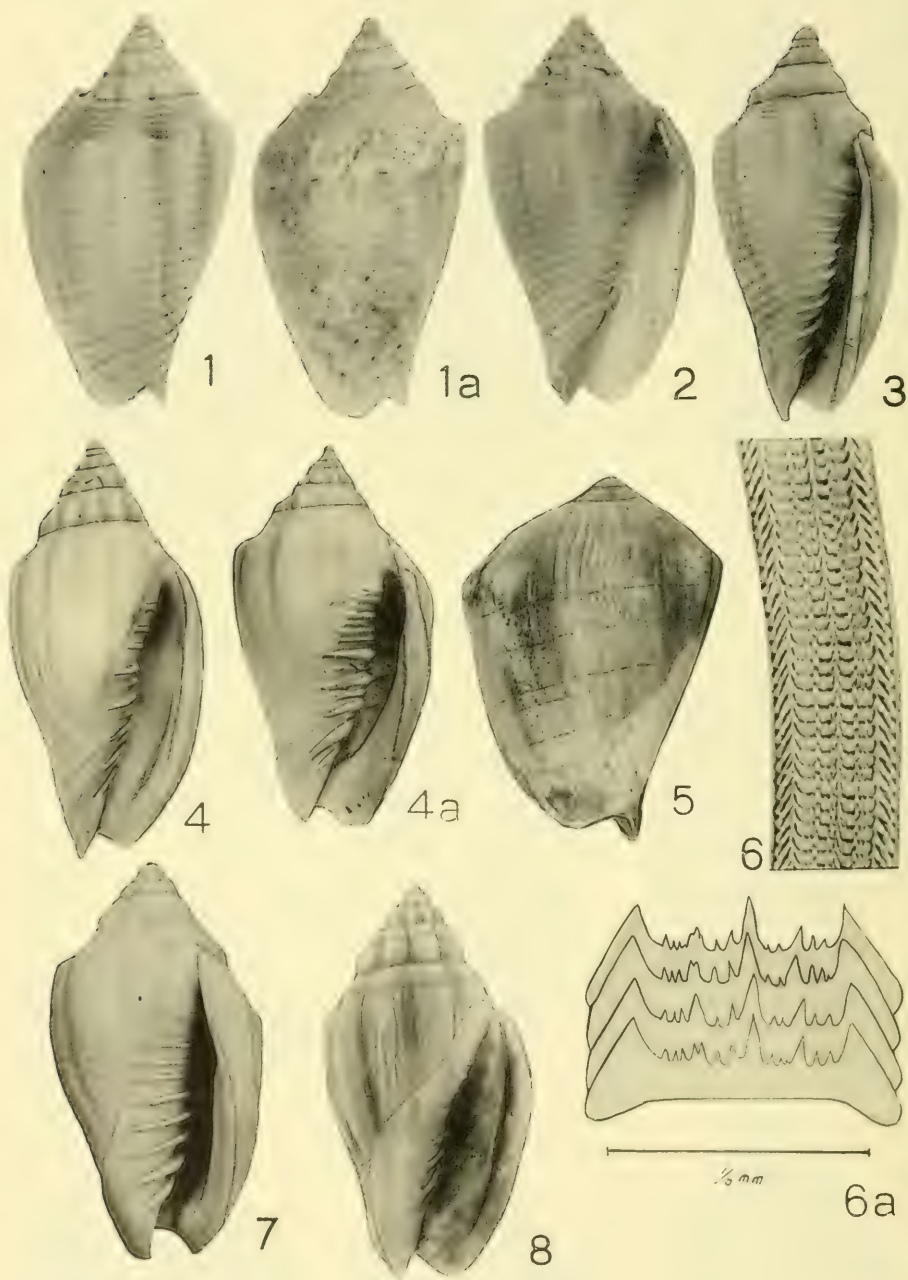
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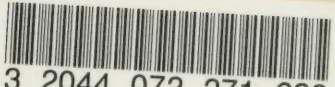
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